



**U.S. Army Corps of Engineers  
Walla Walla District**

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# **Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.**

## **Part 6: McNary Reservoir**

### **FINAL REPORT**

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## **Abstract**

One of the major goals for the U.S. Army Corps of Engineers Dissolved Gas Abatement Study is to identify measures that could reduce levels of dissolved gas supersaturation in the Columbia and Snake Rivers caused by spillway discharges. Attaining this goal could contribute significantly to meeting water quality criteria and lowering gas bubble trauma in resident and migrating fish in these rivers. To achieve this goal, the Corps of Engineers is studying various operational and structural alternatives using field investigations and computational modeling tools to simulate the transport of dissolved gas in the river system.

Part 6 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the McNary Reservoir of the Lower Columbia and Snake River system. The report also describes the initial testing of the FINS individual-based model that can be used to estimate fish exposure to dissolved gas.

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## **Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.**

### **Part 6: McNary Reservoir**

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle, Pacific Northwest Division is developing and applying a two-dimensional hydrodynamic, transport model, and fish exposure model to the Lower Columbia and Snake River systems. This work is an element of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program (DGAS).

Part 6 of the report series describes the application of the model to the McNary Pool of the Columbia and Snake Rivers. The modeled domain encompasses the following region:

- Ice Harbor dam, at Snake rivermile (RM) 9.7
- Clover Island, at about Columbia RM 328.5
- McNary dam, at Columbia RM 292.5.

## **1 Application of the Hydrodynamics and Water Quality Models to McNary Pool**

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Columbia and Snake Rivers that form the McNary Dam pool. The model simulates time-varying distributions of the depth-averaged velocities, water temperature, and total dissolved gas. Further details concerning the model including the governing equations and solutions procedures are provided in Part 1 of the report series (Richmond, Perkins, and Scheibe, 1998).

The section discusses the general aspects of the application of the models to McNary Pool. The data used to assign the bathymetry and boundary conditions are described in Appendix A. Summaries of the field data used in the modeling study are provided in Appendices B through D.

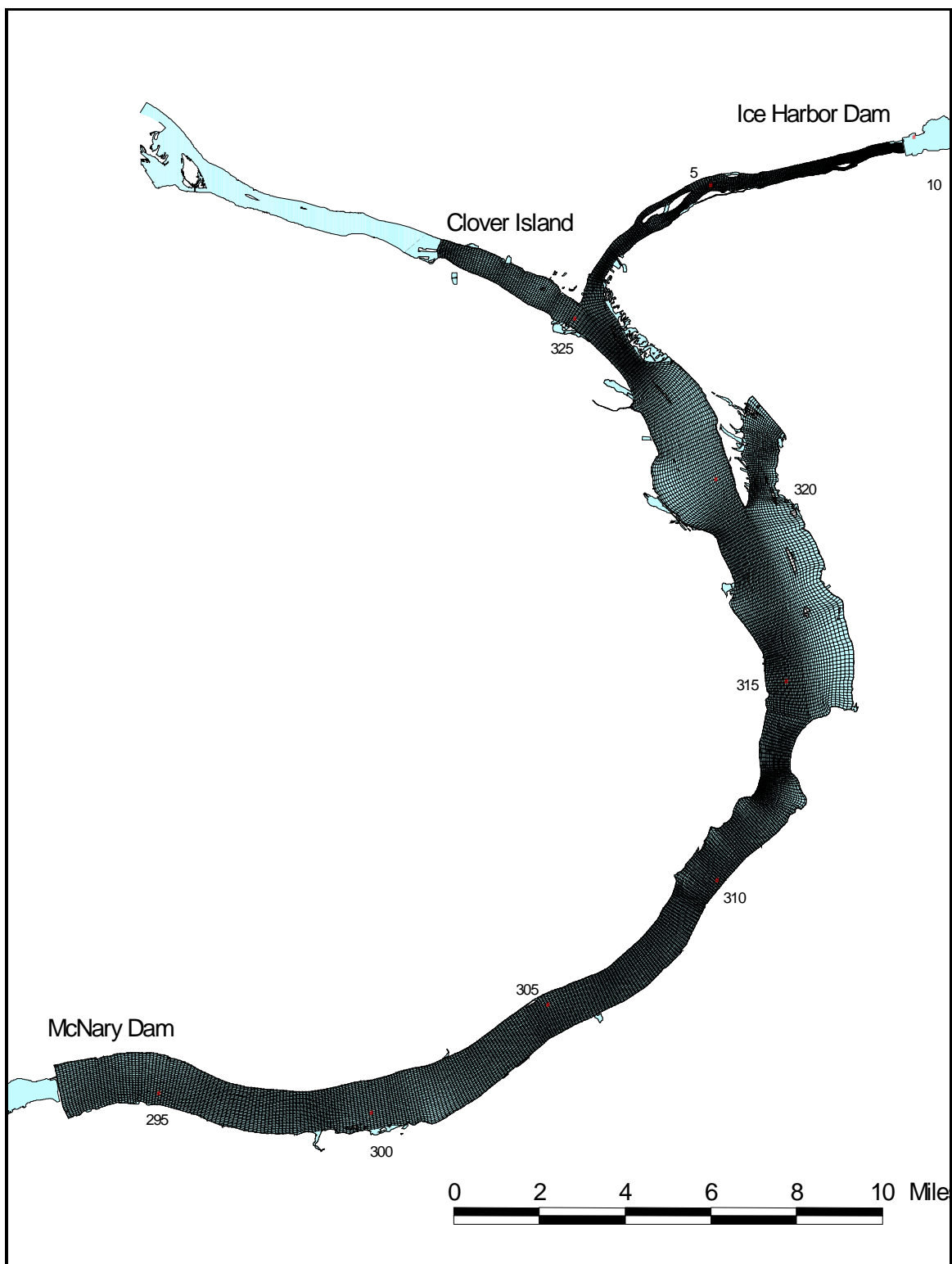
Hydrodynamics were calibrated and verified using 1996 and 1997 tailwater gage and Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature calibration used the Summer 1996 pool study data and verification used the Spring 1996 pool study data.

### **1.1 Model Grid**

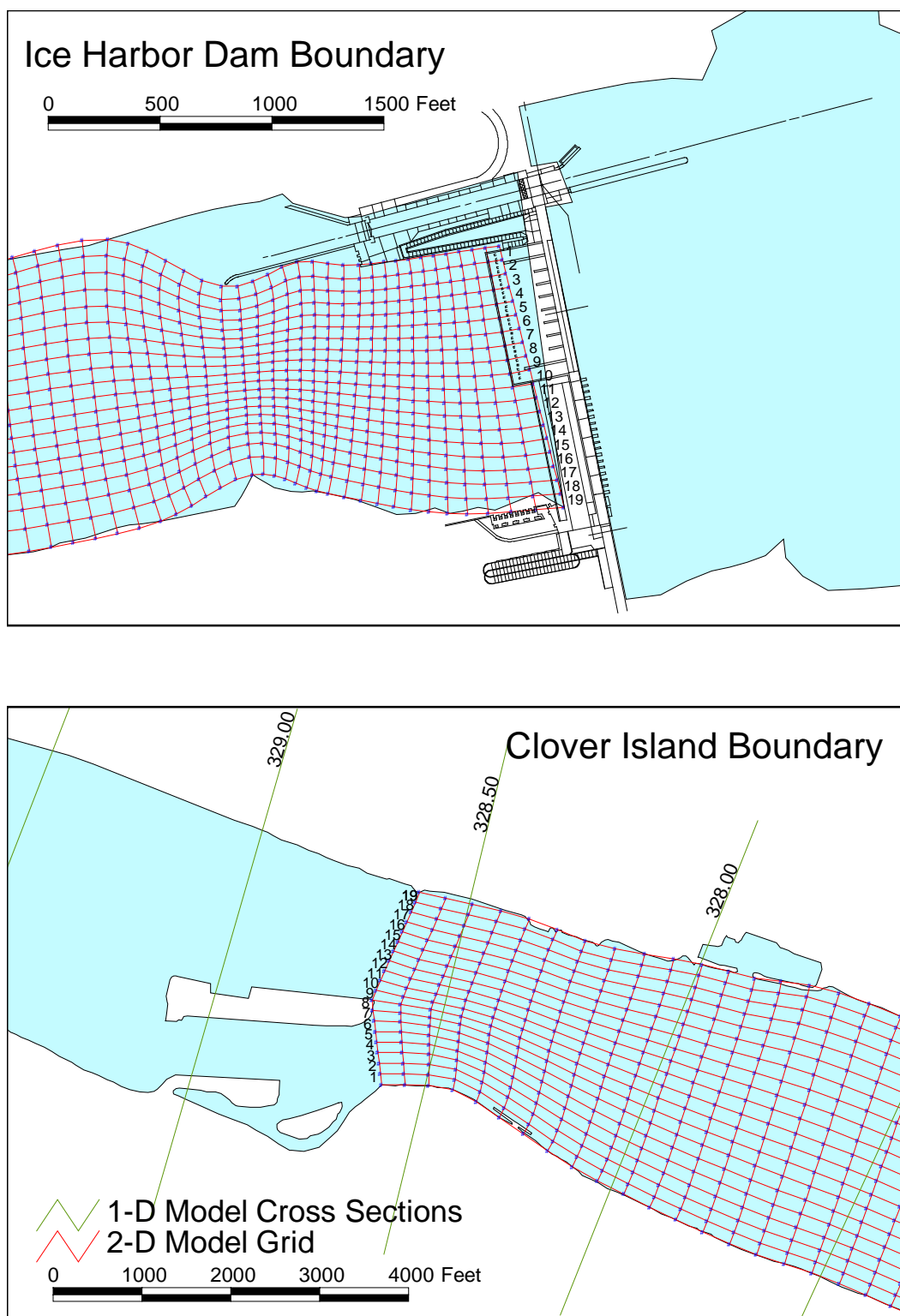
The computational grid was generated using the Gridgen 9.1 code. Gridgen 9.1 is software for the generation of 3D, multiple block, structured grids. The code was developed for NASA Ames Research Center (Steinbrenner and Chawner, 1995).

To create the grid, a data file containing discrete geographical locations that outline the river shoreline was imported to Gridgen. In Gridgen, curves containing the data points were created and joined to enclose 2-dimensional flow regions. Grid spacing was set in each flow region and the grids were smoothed using the Gridgen elliptic solver. The elliptic solver was used to minimize grid twist and skew. The flow regions were then joined end to end in the downstream direction to make up the entire flow domain and the entire 2-dimensional grid was written to file. Once the grid was created bottom elevations in each cell were assigned using the bathymetric data and procedure described in Appendix B.

The model grid for McNary pool is shown in Figure 1. Larger scale maps of the model grid near the Ice Harbor dam and Clover Island boundaries are shown in Figure 2. Note that several small islands were not included in the model and these were replaced with bottom elevation approximately 2 ft below the low water surface elevation (the water is about 2 ft deep where the islands are).



**Figure 1. Model grid for McNary pool.**



**Figure 2. Model grid near Ice Harbor dam and Clover Island.**

## 1.2 Boundary Conditions

At Ice Harbor, spill and powerhouse flows were uniformly spread across the corresponding part of the grid: spill to cells 1 to 10, and powerhouse flow to cells 11 to 19.

Two procedures were used to assign temperature and dissolved gas boundary conditions at Ice Harbor Dam.

The first procedure to assign boundary conditions using the forebay dissolved gas data and a dissolved gas sourcing function. Spill and powerhouse flow temperatures that were assumed to be equal to each other and equal to the forebay temperature. Powerhouse TDG concentrations were set using instrumentation in the forebay. Spillway TDG concentrations were computed using the Ice Harbor sourcing function, presented by Schnieder and Wilhelms (1997):

$$S_s = 136.8 - 42.0e^{-3.4 \times 10^{-5} Q_s} \quad (1)$$

where

$S_s$  = TDG saturation of spillway flow, percent; and

$Q_s$  = spillway flow, cfs.

Note that this sourcing function was developed prior to the installation of spill deflectors in 1997. The Spring 1997 study (Appendix D) took place after the deflectors were installed. Consequently, the calculated gas concentrations in the spillway using equation (1) may not be representative of the actual conditions in 1997. Therefore an updated gas production relationship will be needed to apply the first procedure for the Spring 1997 field study.

The second procedure was to use the furthest upstream dissolved gas monitors to assign both incoming flow temperature and dissolved gas concentrations. In the Spring and Summer 1996 instruments were available at locations laterally across the river near the end of the navigation lock guide wall (see Figure 2). During the Spring 1997 period the nearest monitors were located at Snake River Mile 6.1 approximately 3.7 miles downstream from Ice Harbor Dam.

The Clover Island boundary is located just below Clover Island near Kennewick, Washington at about Columbia RM 289.5. A one-dimensional hydrodynamic model was used to estimate Columbia River discharge and stage at this location. Figure 2 shows the location of one-dimensional cross-sections locations relative to the model grid. The one-dimensional model used operations at Priest Rapids, McNary, and Ice Harbor dams and tributary inflows from the Yakima and Walla Rivers.

At the McNary Dam boundary the measured forebay elevation was used as the downstream boundary condition for the model.

Air and dew point temperature, wind speed, barometric pressure, and net incoming solar radiation are the meteorological data used as model boundary conditions. These were assigned uniformly over the entire McNary Pool. A single latitude and longitude was used for the entire McNary pool: 46°N and 119°W. The data sources and data are summarized in Appendices B through E. Surface heat flux was computed using the method described in Appendix A.

### 1.3 Hydrodynamics Calibration and Verification

The model hydrodynamics were calibrated primarily using the Ice Harbor tailwater elevation gage. Due to instrumentation problems the horizontal coordinates of the ADCP data were subject to uncertain errors. Therefore, at this time, use of the ADCP data was restricted to qualitative comparisons with the model simulations.

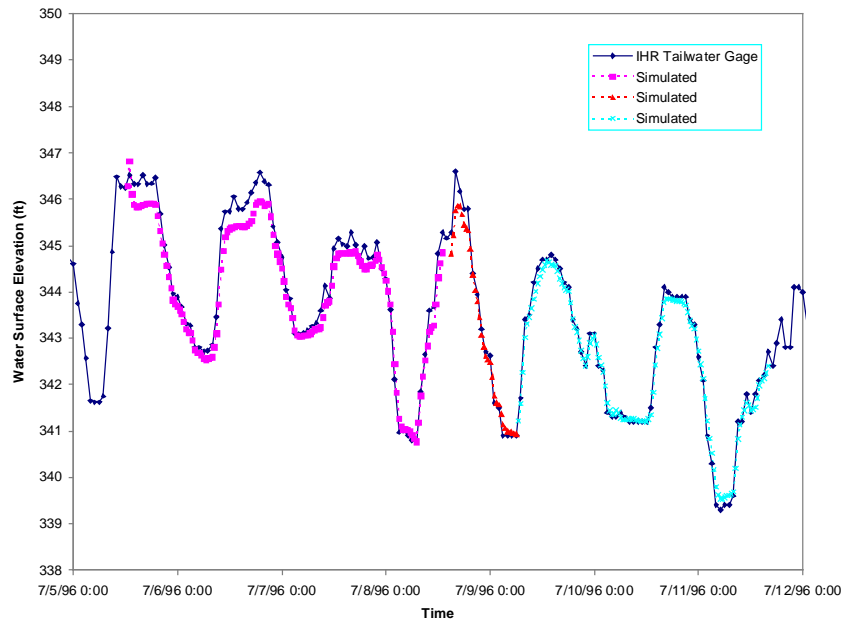
In all simulations in this report a time step of 50 seconds was used. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of 0.2 ft<sup>2</sup>/s.

#### 1.3.1 Ice Harbor Tailwater

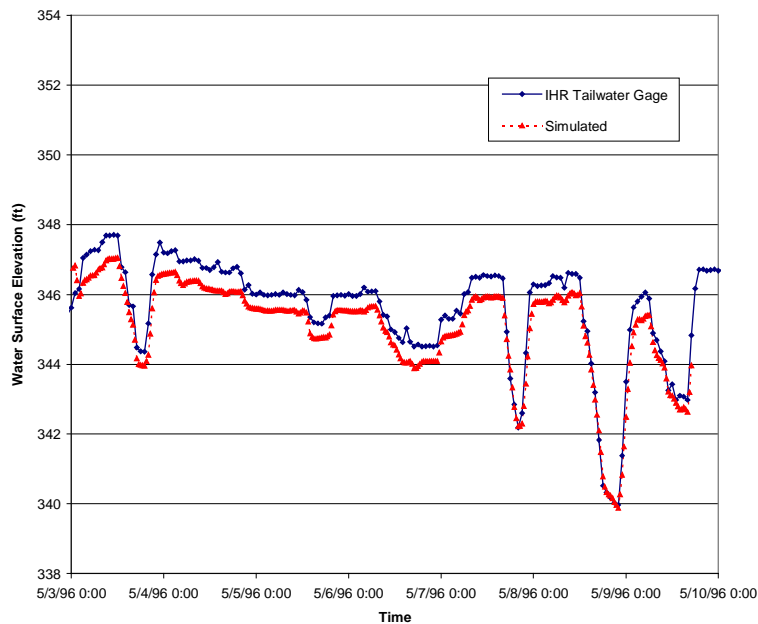
The first step in the calibration procedure was to select a spatially uniform value of the Manning roughness coefficient that would yield computed water surface elevations in satisfactory agreement with the Ice Harbor Dam tailwater gage. The Summer 1996 pool study period was selected because ADCP velocity measurements were also available for that period. Simulations were performed using Manning n values in the range of 0.026 to 0.030. Figure 3 compares the model simulation and measured tailwater elevation for a n-value of 0.027 which was chosen as the final parameter value to be used in the remainder of the McNary Pool simulations. The model simulates the temporal changes well using hourly dam operations data. The tailwater is somewhat under predicted (less than 0.5 difference) at stages above 345 ft.

The selected n-value was verified for both the Spring 1996 and 1997 pool study periods. The verification results are shown in Figure 4 and Figure 5. As in the Summer 1996 case the model under predicts when the elevation is above 345 ft. However, during the Spring 1997 case the model slightly over predicts the elevation. The temporal variations are not as well simulated in 1997 case and could be the result of using hourly operations data. The inconsistency could be related to the fact that turbine units 3 and 5 were down most of 1996 and unit 5 was down for all of 1997. Further simulations using the 5 minute operations data could be performed to verify whether the gage elevation differences and temporal differences can be addressed using finer temporal and spatial inflow conditions.

To approximate the effect of flow division that occurs near Columbia River Mile 324 where the small islands were not included the manning n was increased to 0.050.

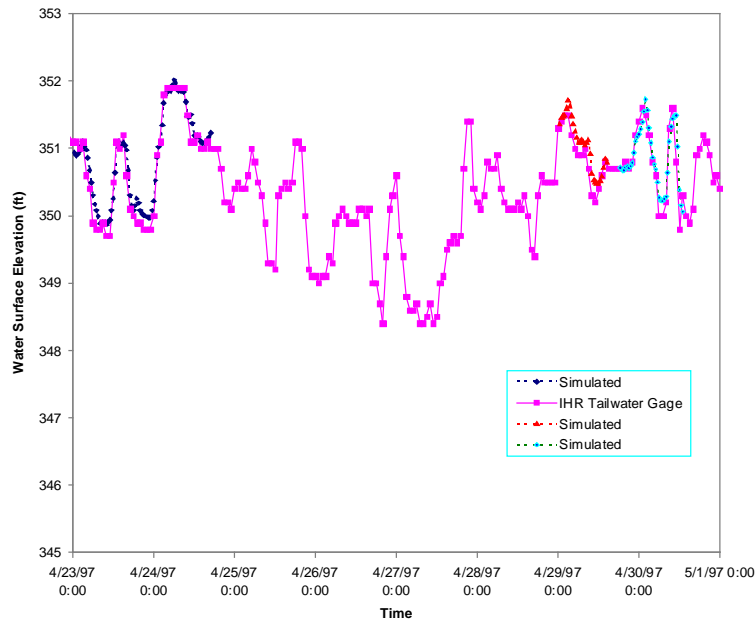


**Figure 3. Comparison of simulated (Manning  $n=0.027$ ) and measured water surface elevation at the Ice Harbor Dam tailwater gage for the Summer 1996 study period.**



**Figure 4. Comparison of simulated (Manning  $n=0.027$ ) and measured water surface elevation at the Ice Harbor Dam tailwater gage for the Spring 1996 study period.**

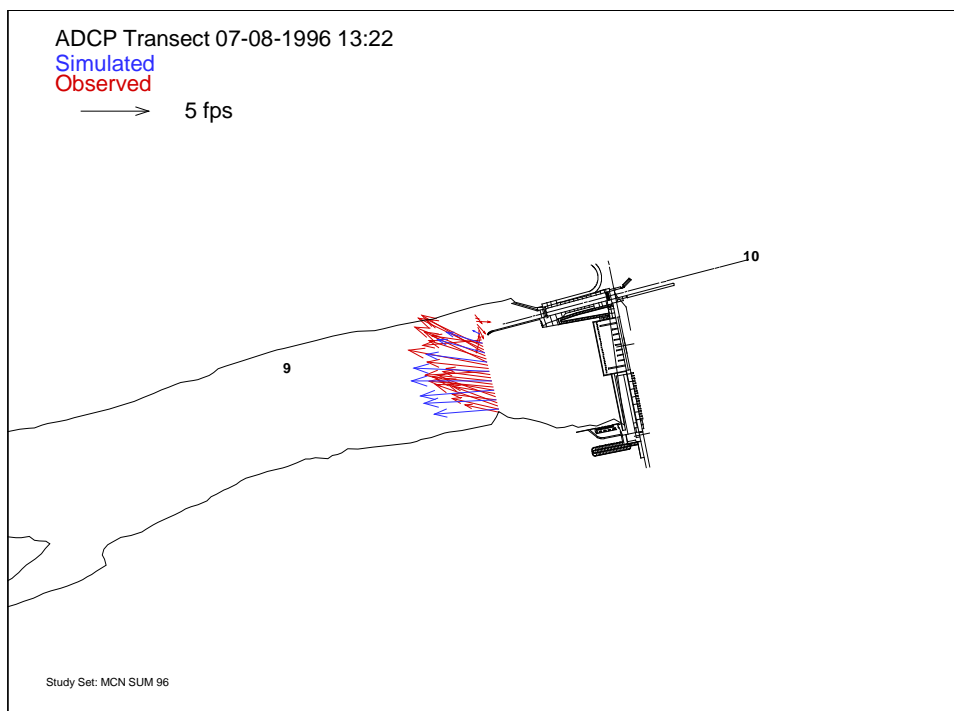




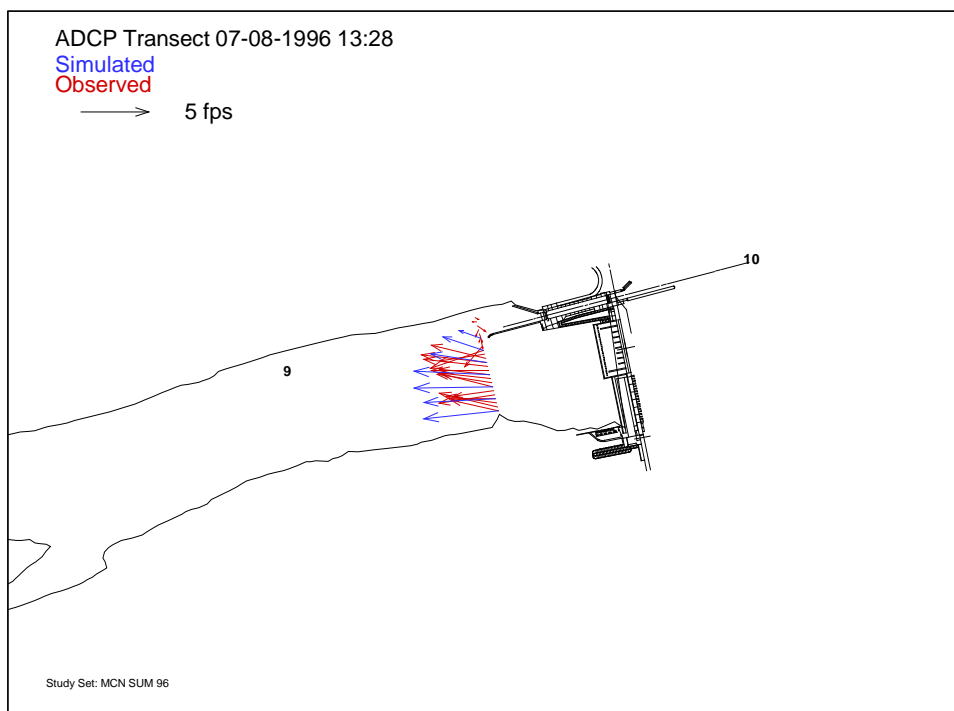
**Figure 5. Comparison of simulated (Manning  $n=0.027$ ) and measured water surface elevation at the Ice Harbor Dam tailwater gage for the Spring 1997 study period.**

### **1.3.2 1996 ADCP Data**

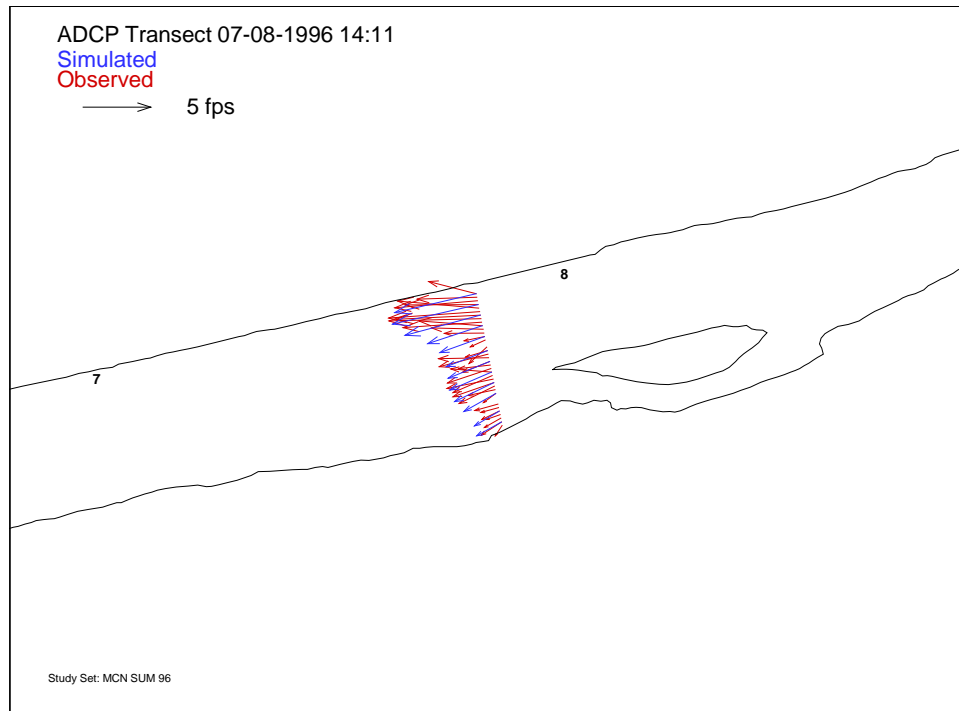
Once the manning  $n$  value was selected the model was run for the operational conditions (Clover Island flow, Ice Harbor spill and powerhouse flow, and McNary forebay elevation) that existed when the 1996 ADCP measurements were performed. The manning  $n$  value was not altered from the value of 0.027 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged 1996 ADCP data in Figure 6 through Figure 22.



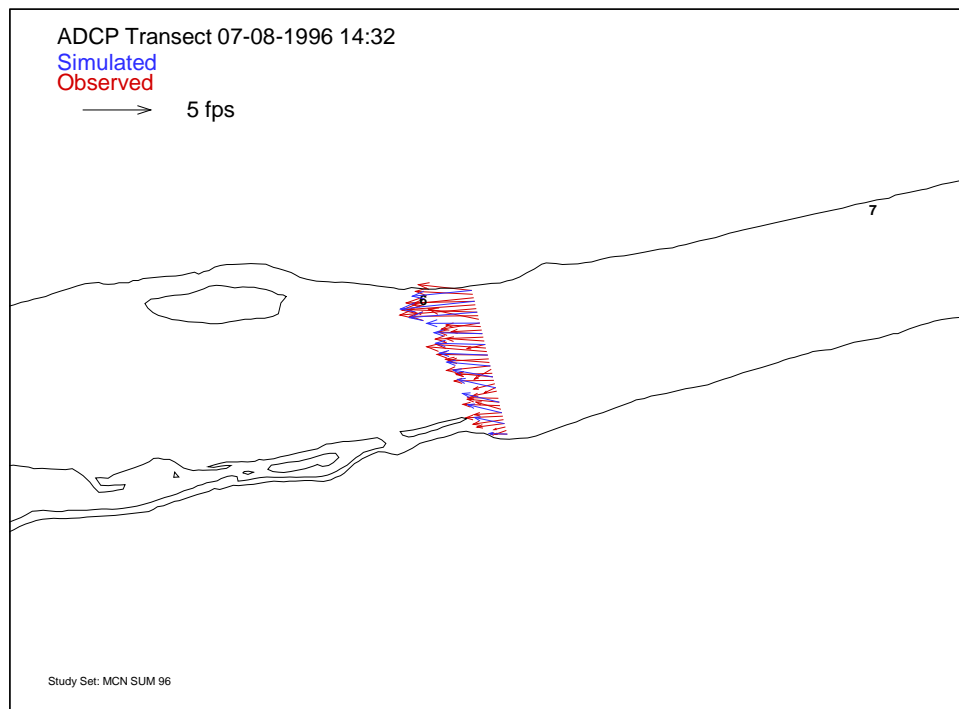
**Figure 6. Simulated and observed depth-averaged velocities near Ice Harbor Dam on 7-8-1996.**



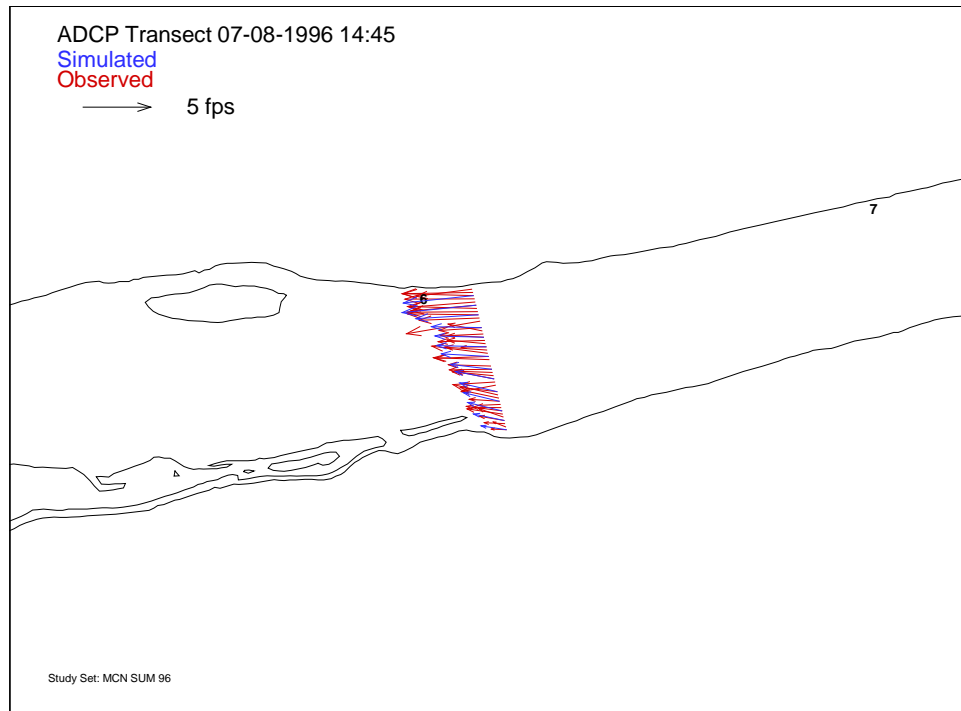
**Figure 7. Simulated and observed depth-averaged velocities near Ice Harbor Dam on 7-8-1996.**



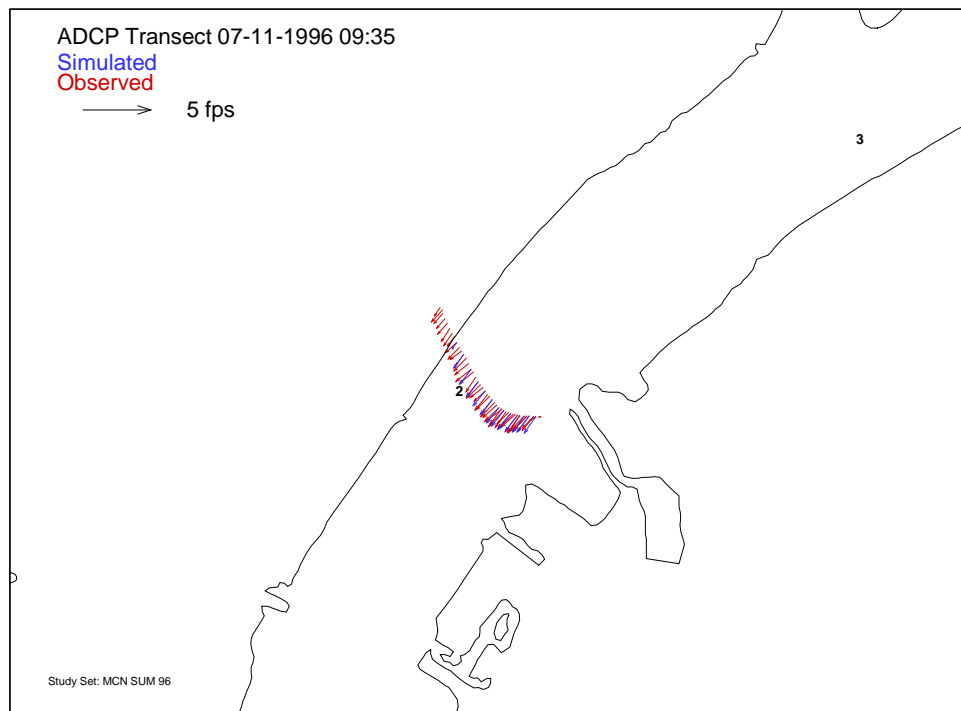
**Figure 8. Simulated and observed depth-averaged velocities near Snake River Mile 8 on 7-8-1996.**



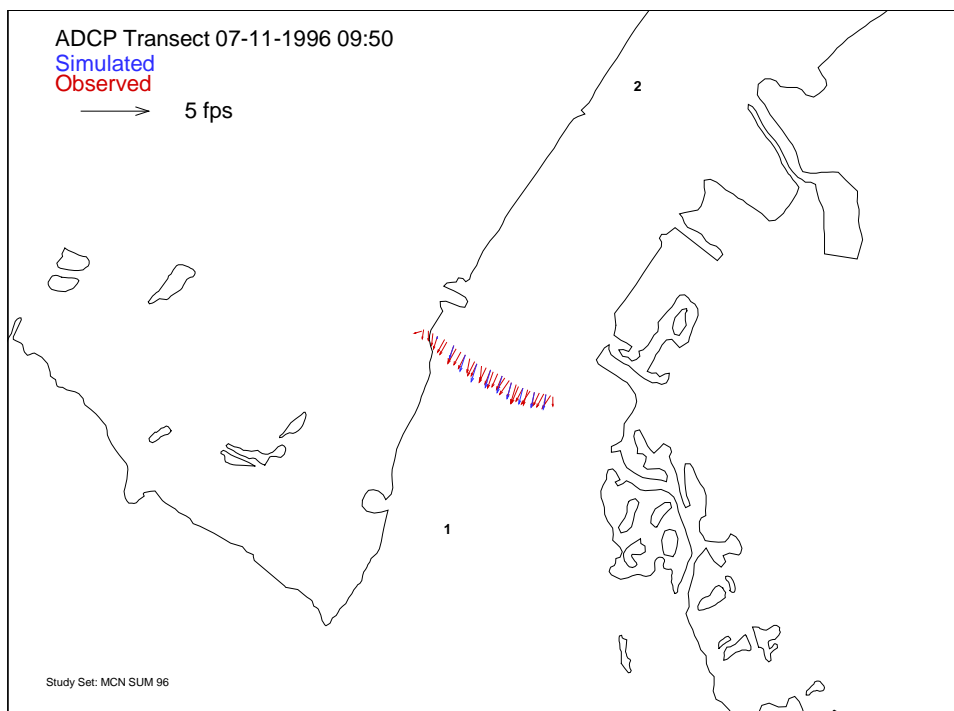
**Figure 9. Simulated and observed depth-averaged velocities near Snake River Mile 6 on 7-8-1996.**



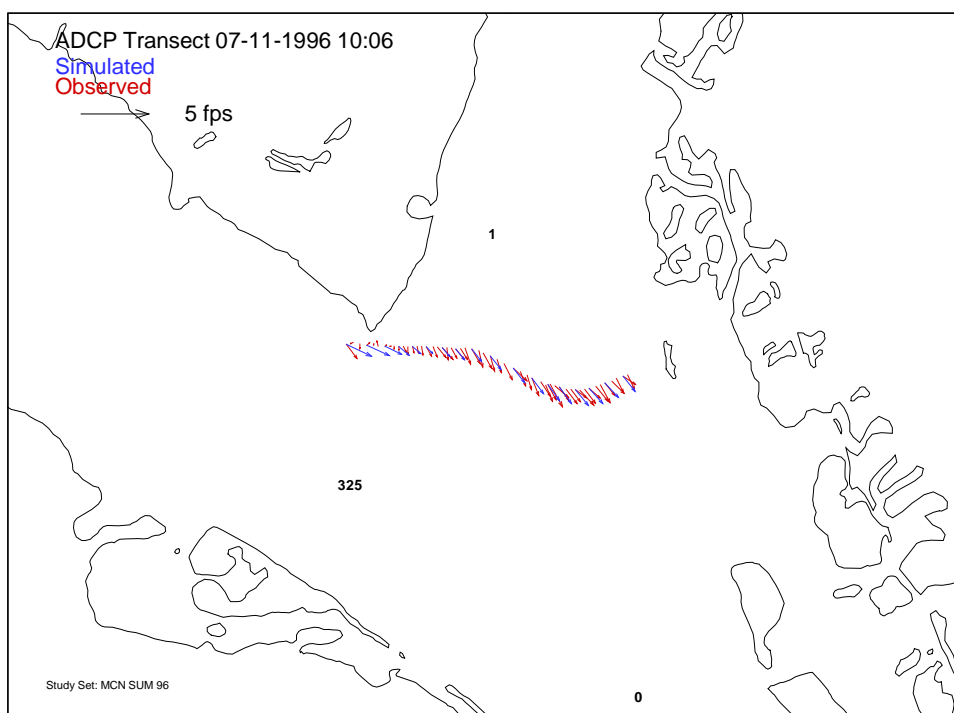
**Figure 10. Simulated and observed depth-averaged velocities near Snake River Mile 6 on 7-8-1996.**



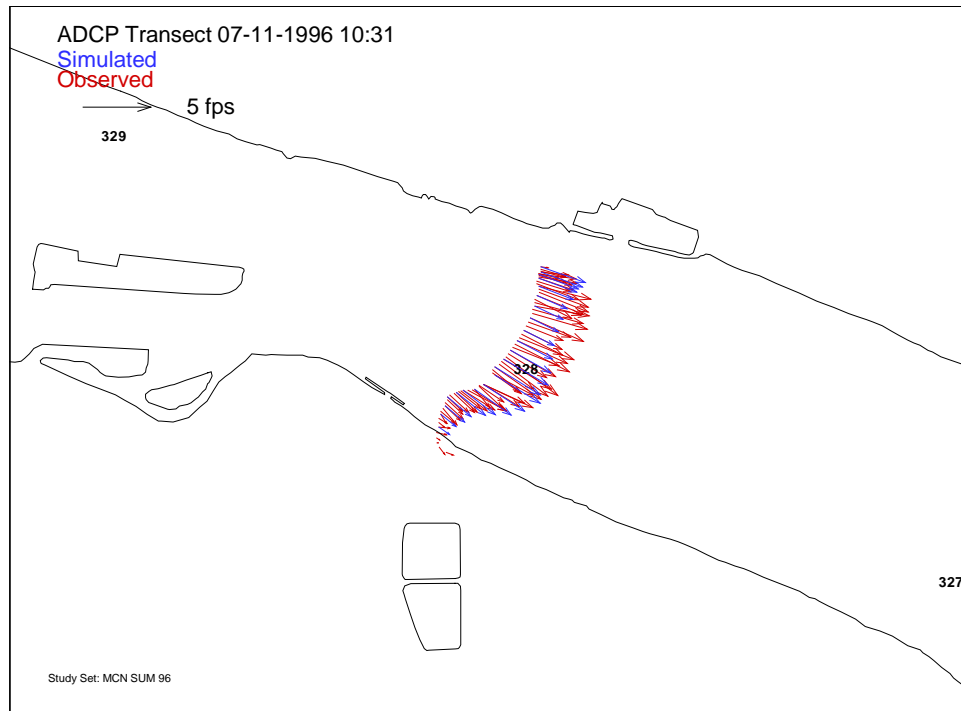
**Figure 11. Simulated and observed depth-averaged velocities near Snake River Mile 2 on 7-11-1996.**



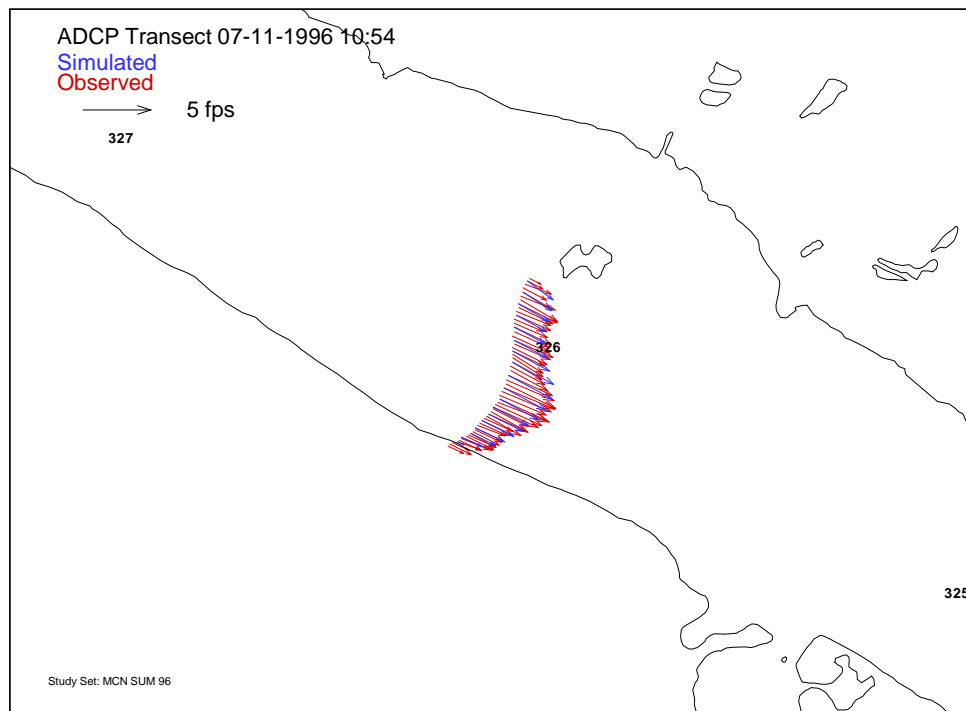
**Figure 12. Simulated and observed depth-averaged velocities near Snake River Mile 1.5 on 7-11-1996.**



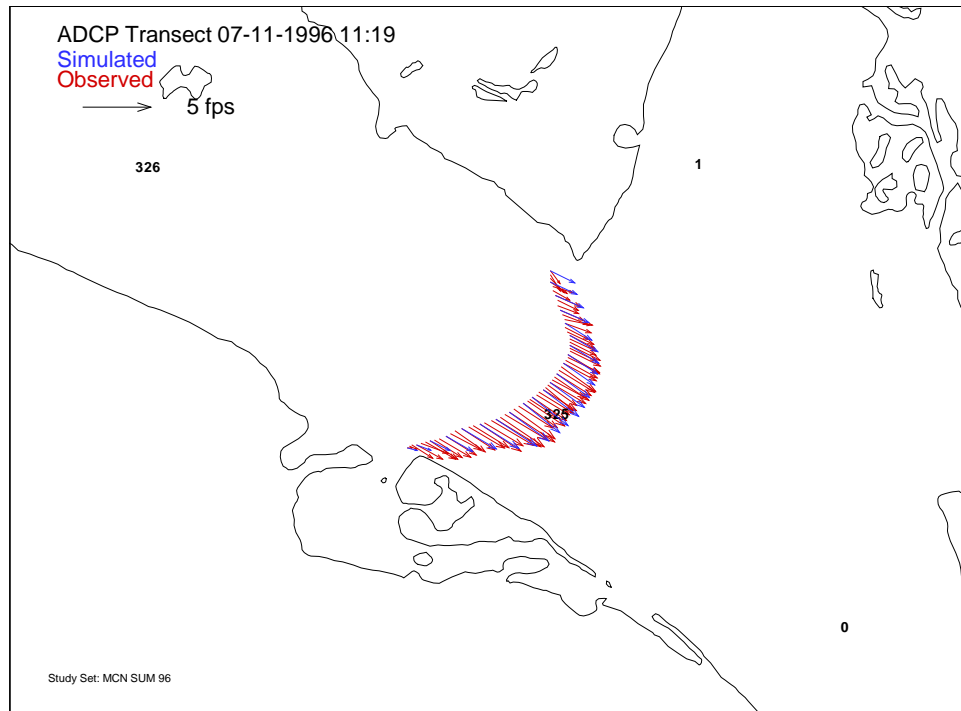
**Figure 13. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers 2 on 7-11-1996.**



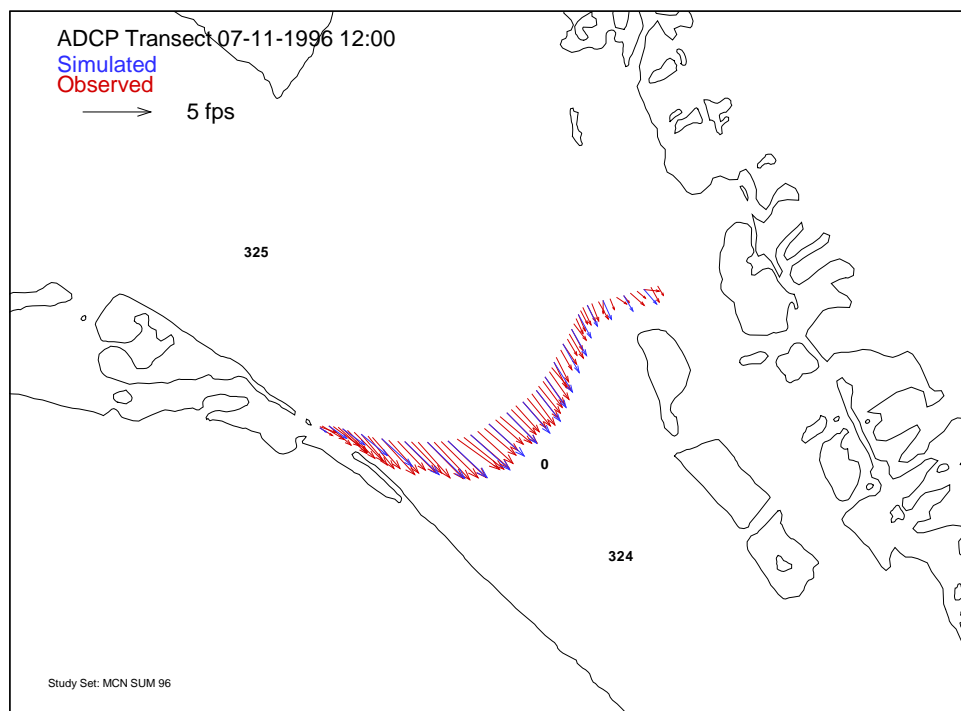
**Figure 14. Simulated and observed depth-averaged velocities near Columbia River Mile 328 on 7-11-1996.**



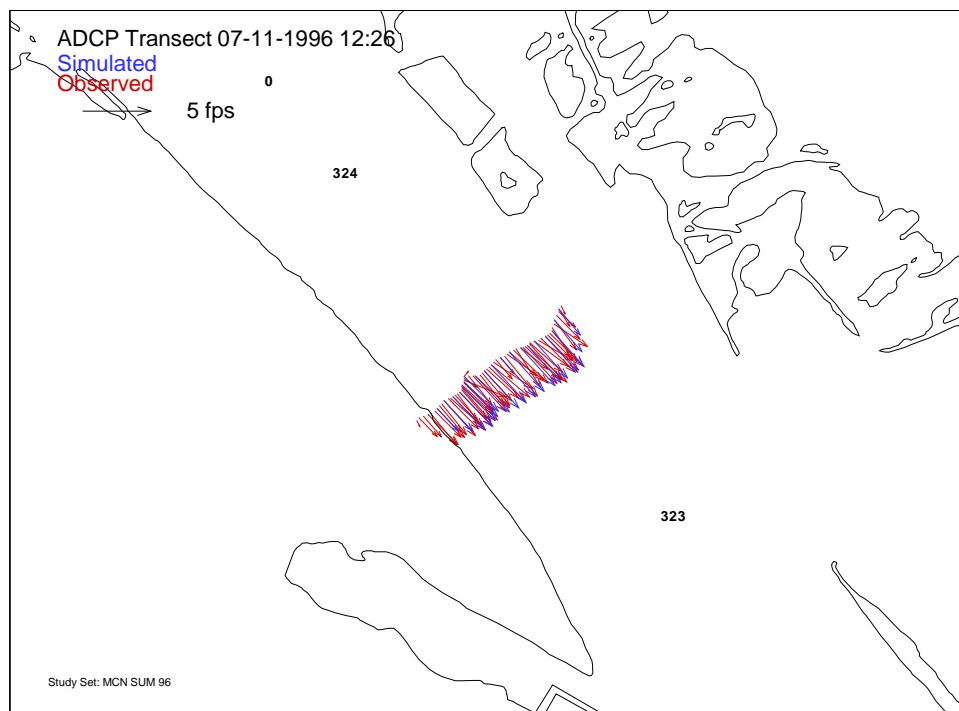
**Figure 15. Simulated and observed depth-averaged velocities near Columbia River Mile 326 on 7-11-1996.**



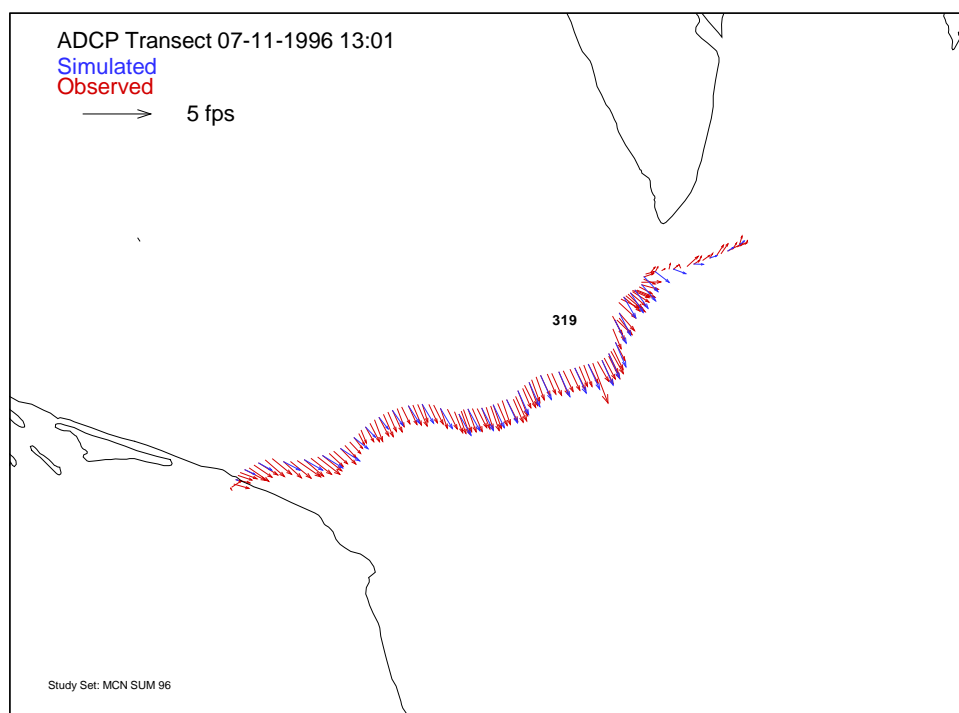
**Figure 16. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 7-11-1996.**



**Figure 17. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 7-11-1996.**

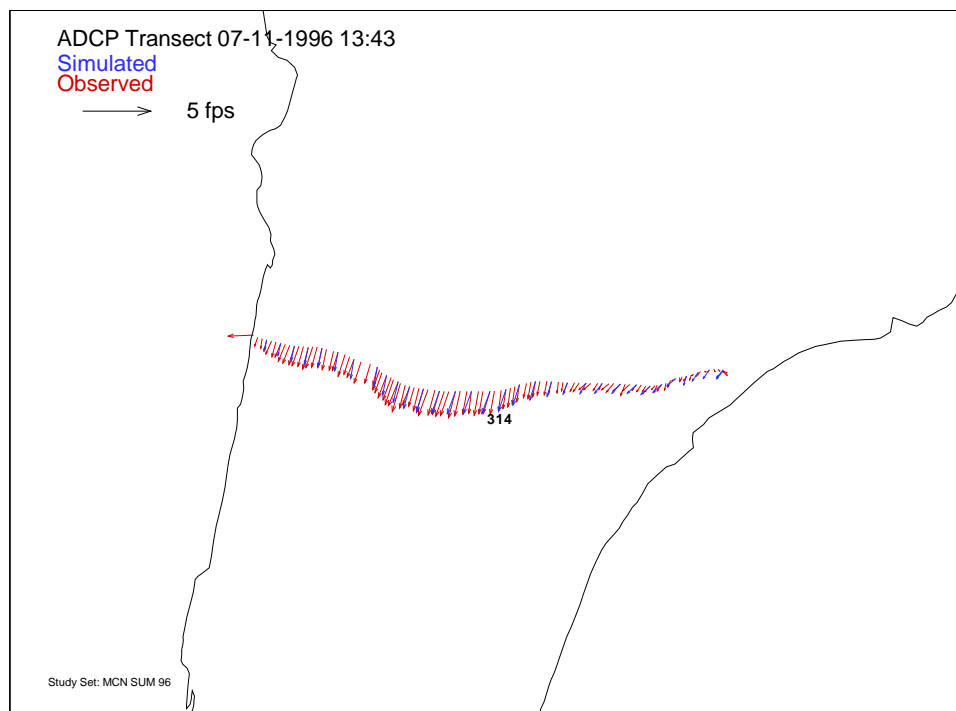


**Figure 18. Simulated and observed depth-averaged velocities near Columbia River Mile 325 on 7-11-1996.**

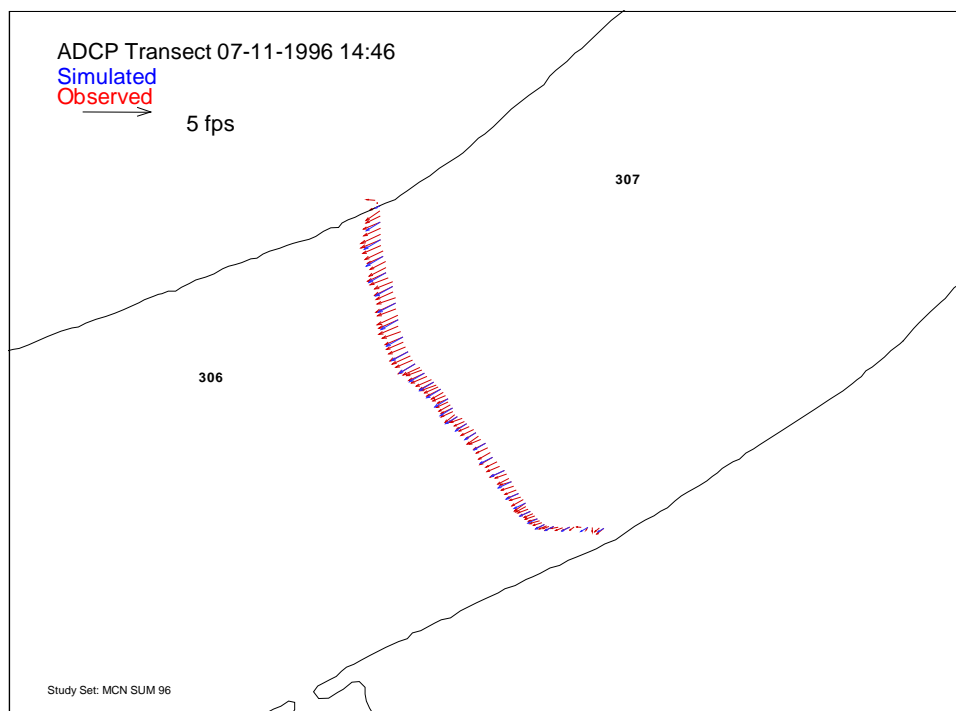


**Figure 19. Simulated and observed depth-averaged velocities near Columbia River Mile 319 on 7-11-1996.**

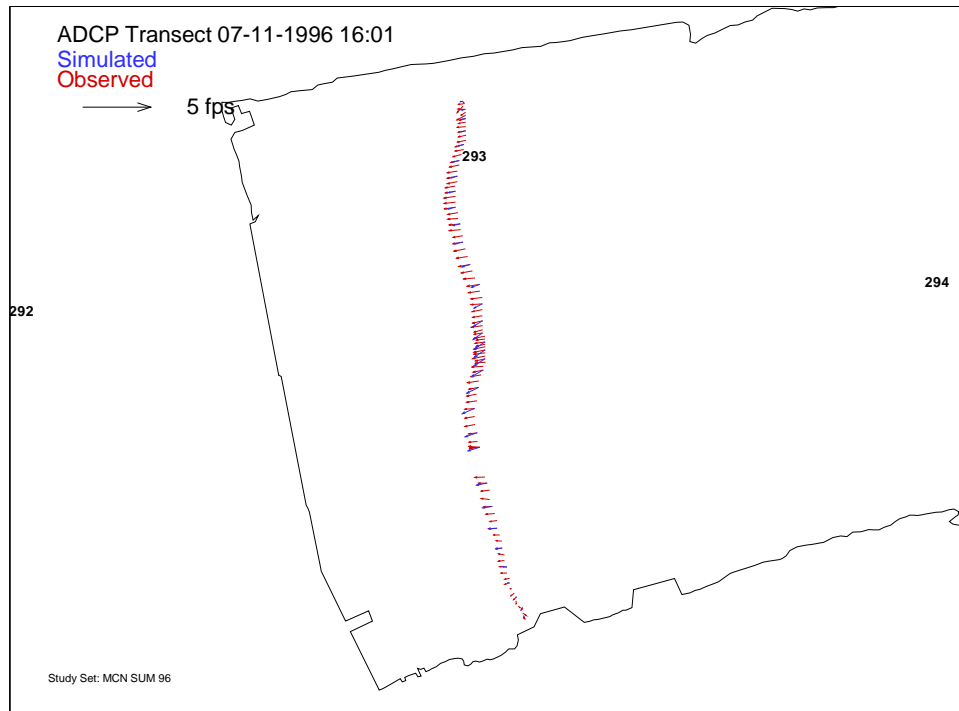




**Figure 20. Simulated and observed depth-averaged velocities near Columbia River Mile 314 on 7-11-1996.**



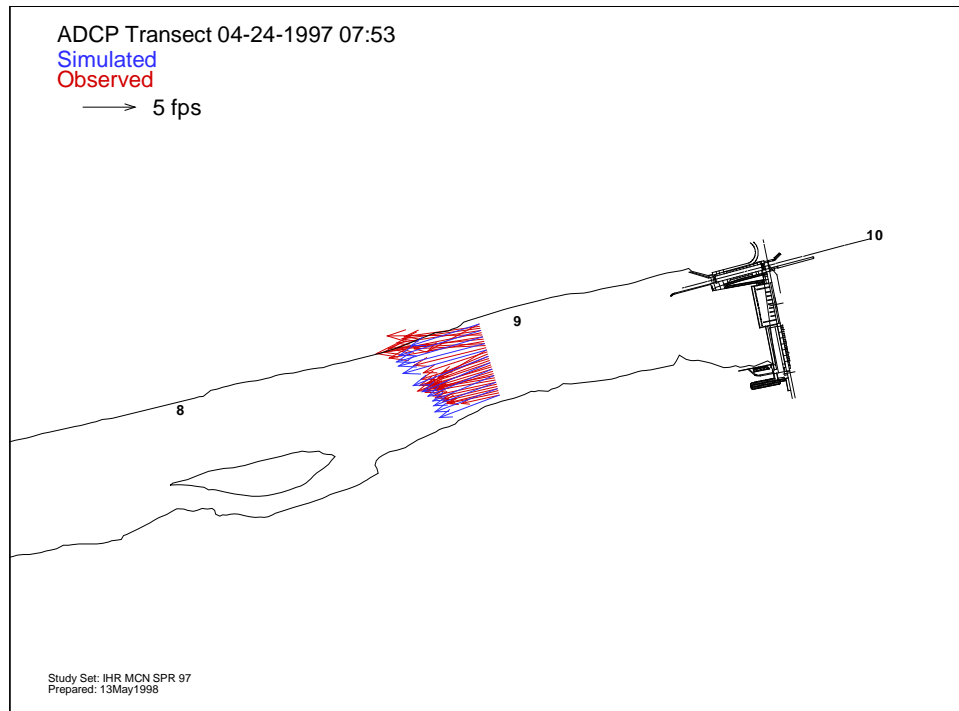
**Figure 21. Simulated and observed depth-averaged velocities near Columbia River Mile 306.5 on 7-11-1996.**



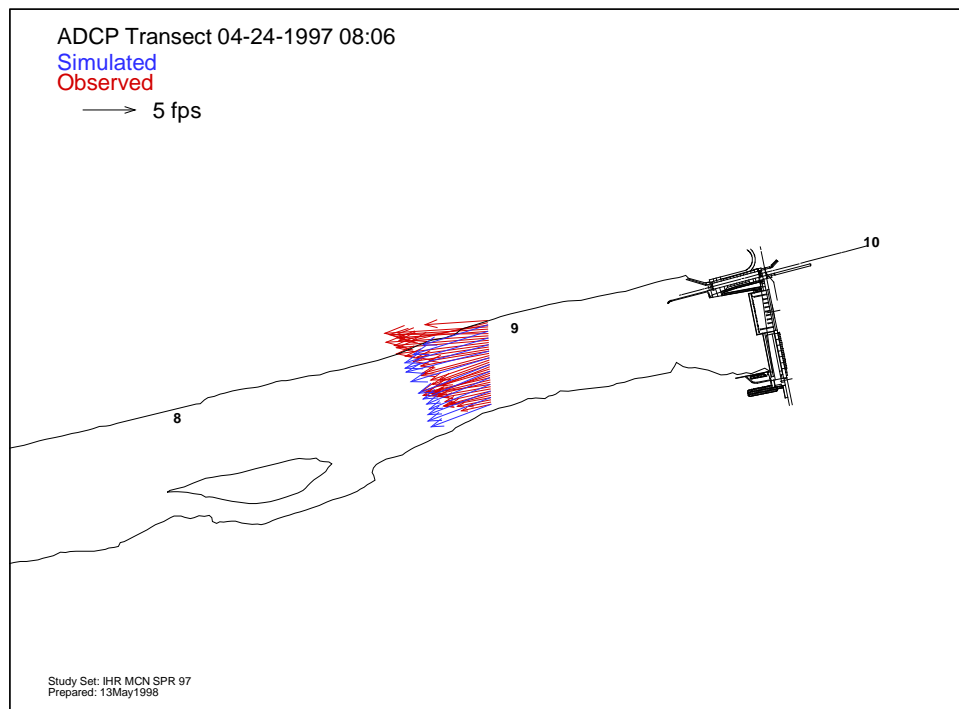
**Figure 22. Simulated and observed depth-averaged velocities in the McNary Dam forebay near Columbia River Mile 293 on 7-11-1996.**

### ***1.3.3 1997 ADCP Data***

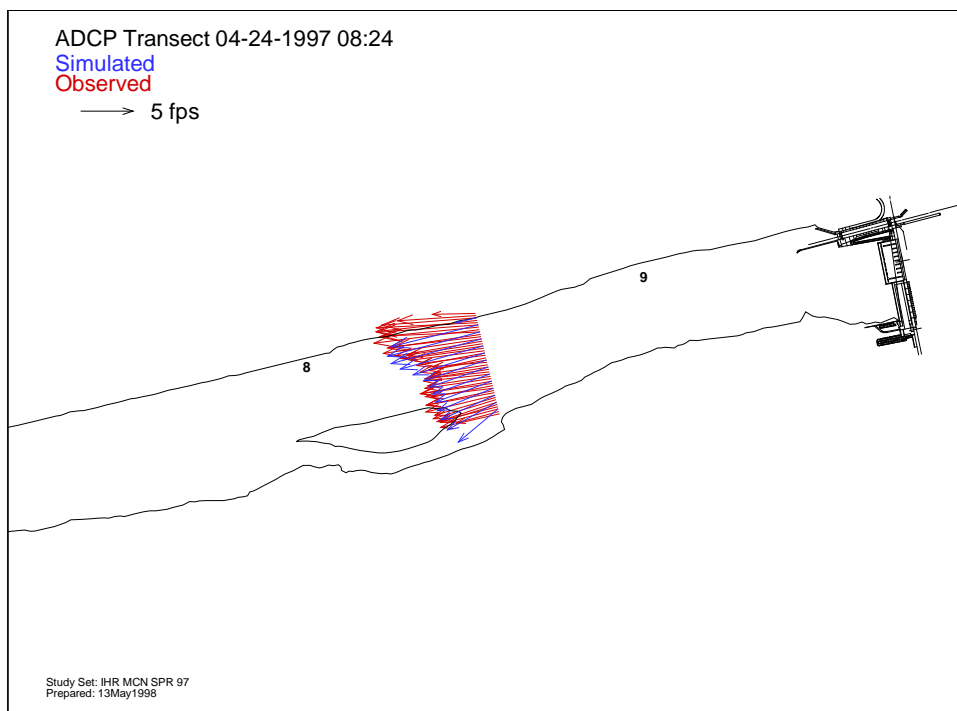
As was the case for the 1996 ADCP case, the model was run using operational conditions (Clover Island flow, Ice Harbor spill and powerhouse flow, and McNary forebay elevation) that existed when the 1997 ADCP measurements were performed. Again, the Manning  $n$  value was not altered from the value of 0.027 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged 1997 ADCP data in Figure 23 through Figure 48.



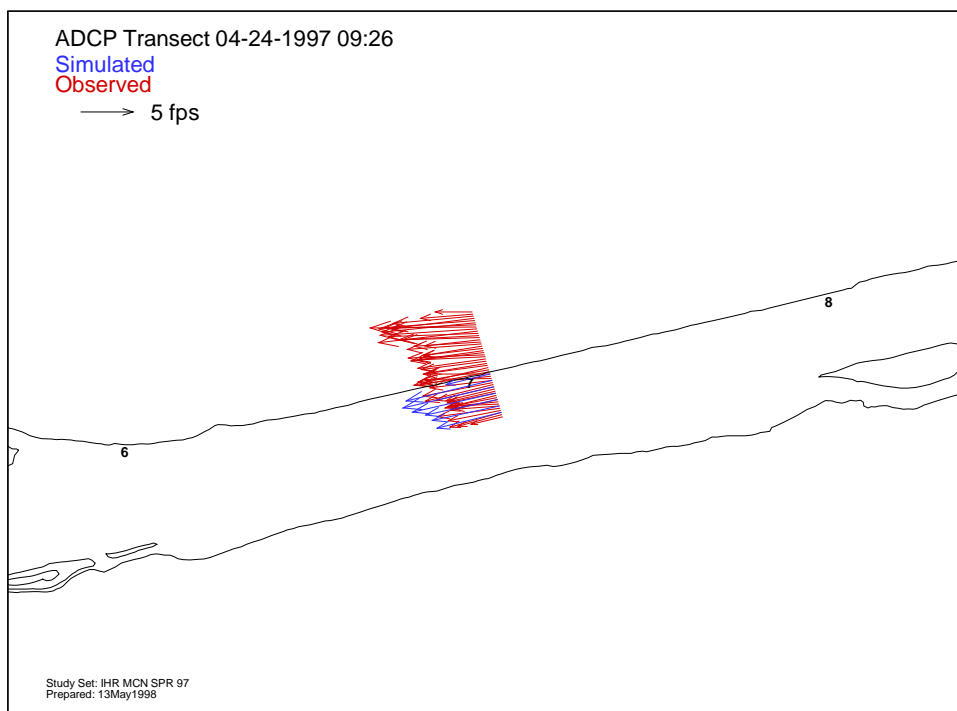
**Figure 23. Simulated and observed depth-averaged velocities near Ice Harbor Dam on 4-24-1997.**



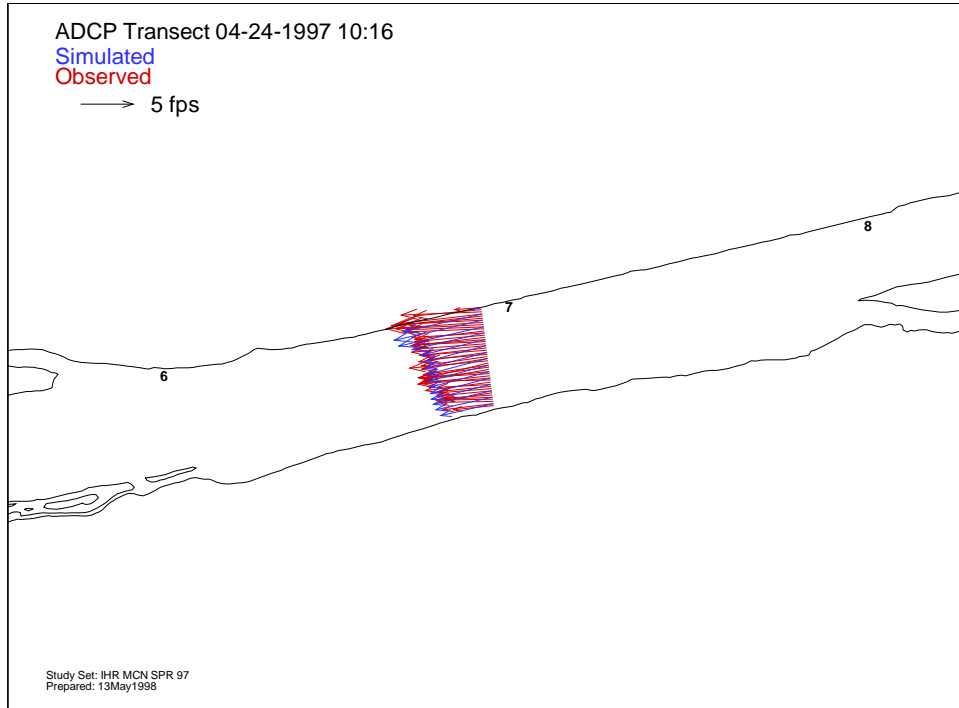
**Figure 24. Simulated and observed depth-averaged velocities near Ice Harbor Dam on 4-24-1997.**



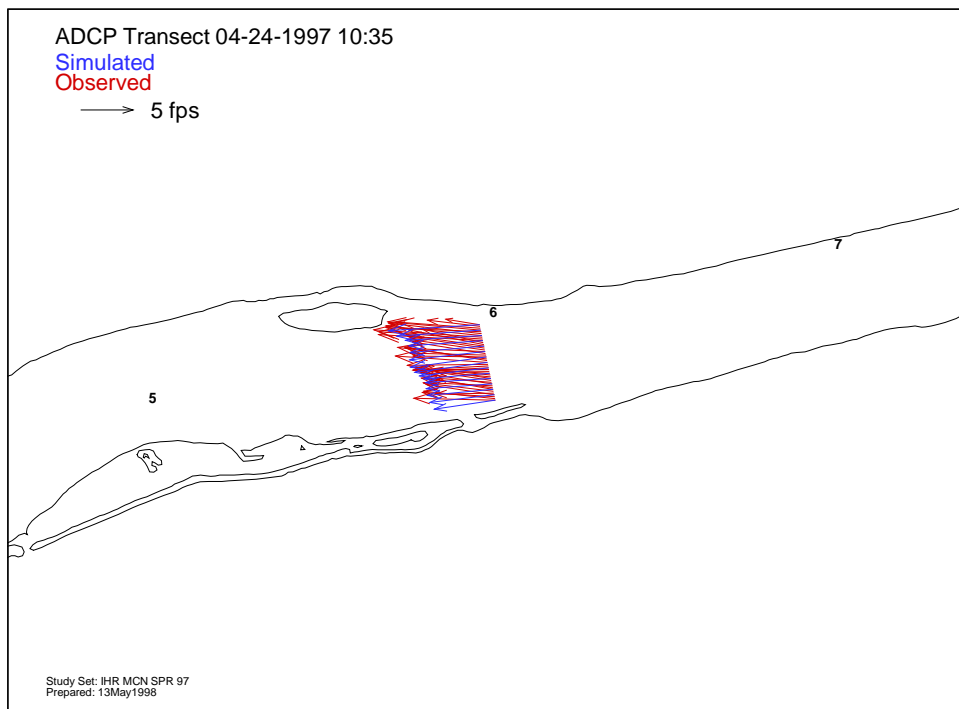
**Figure 25. Simulated and observed depth-averaged velocities near Ice Harbor Dam on 4-24-1997.**



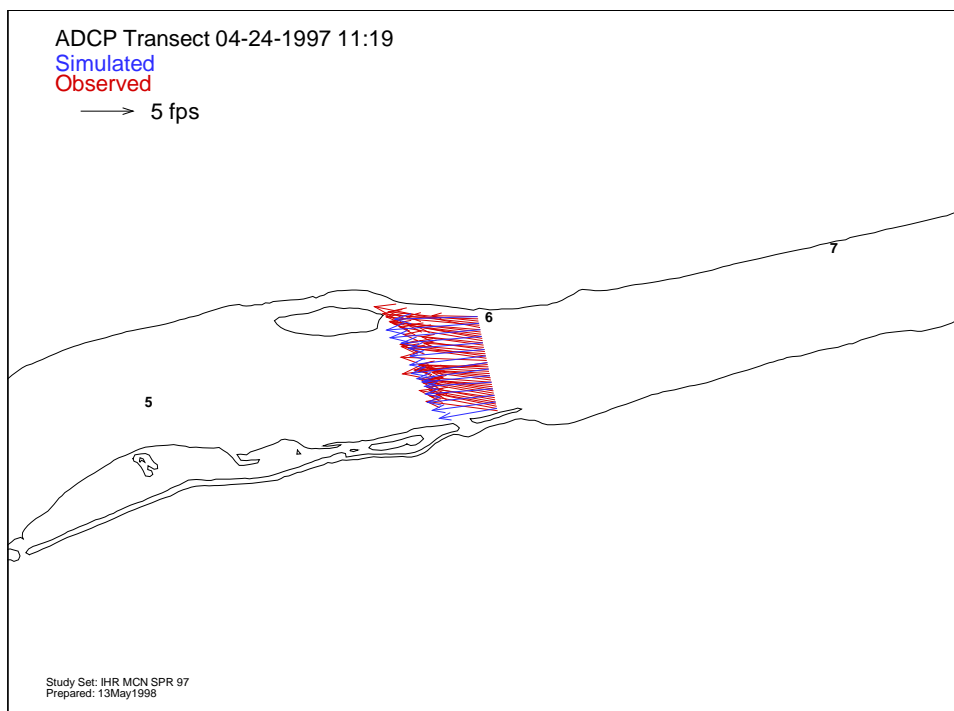
**Figure 26. Simulated and observed depth-averaged velocities near Snake River Mile 7 on 4-24-1997.**



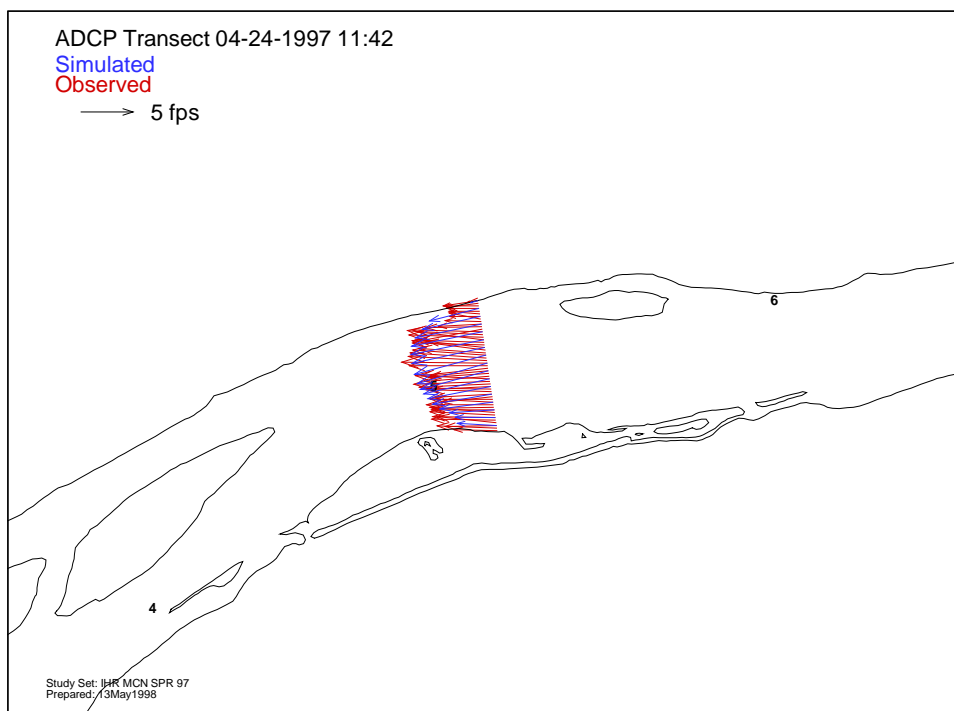
**Figure 27. Simulated and observed depth-averaged velocities near Snake River Mile 7 on 4-24-1997.**



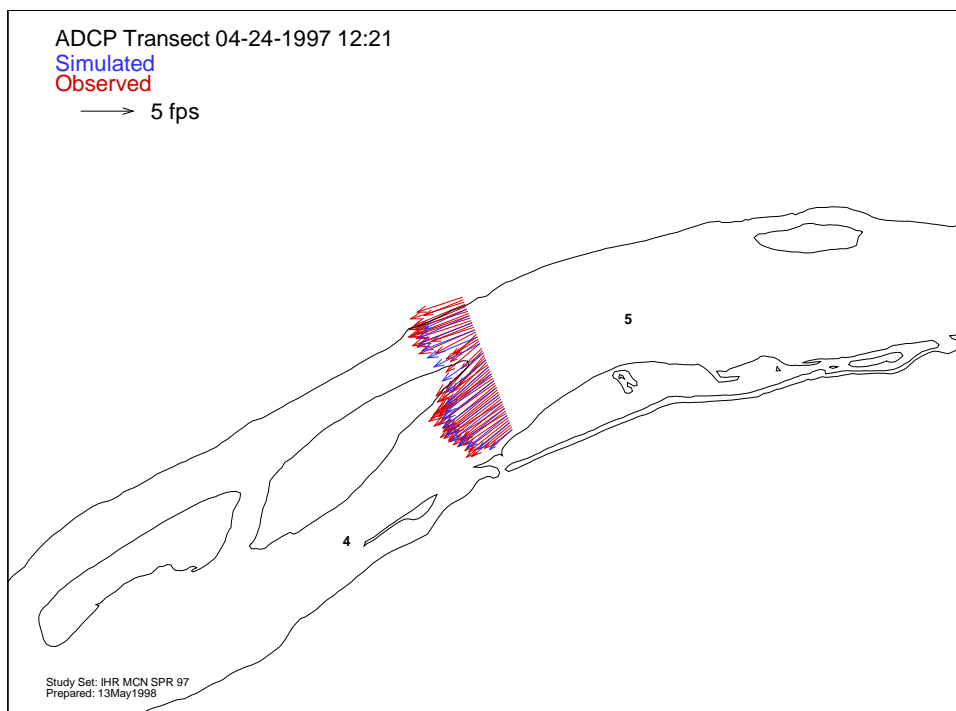
**Figure 28. Simulated and observed depth-averaged velocities near Snake River Mile 6 on 4-24-1997.**



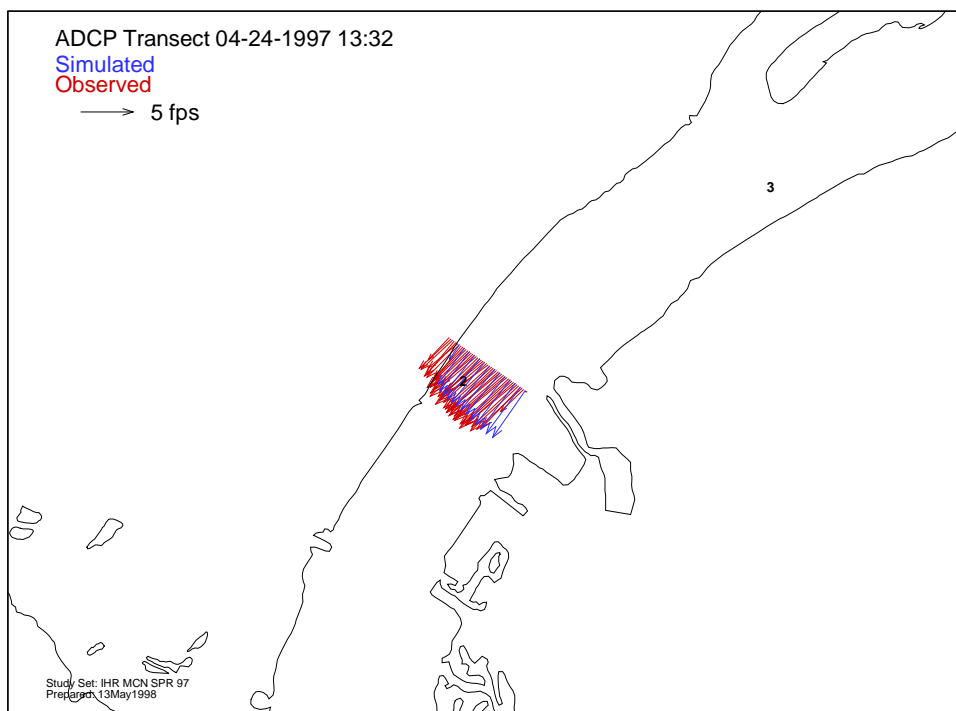
**Figure 29. Simulated and observed depth-averaged velocities near Snake River Mile 6 on 4-24-1997.**



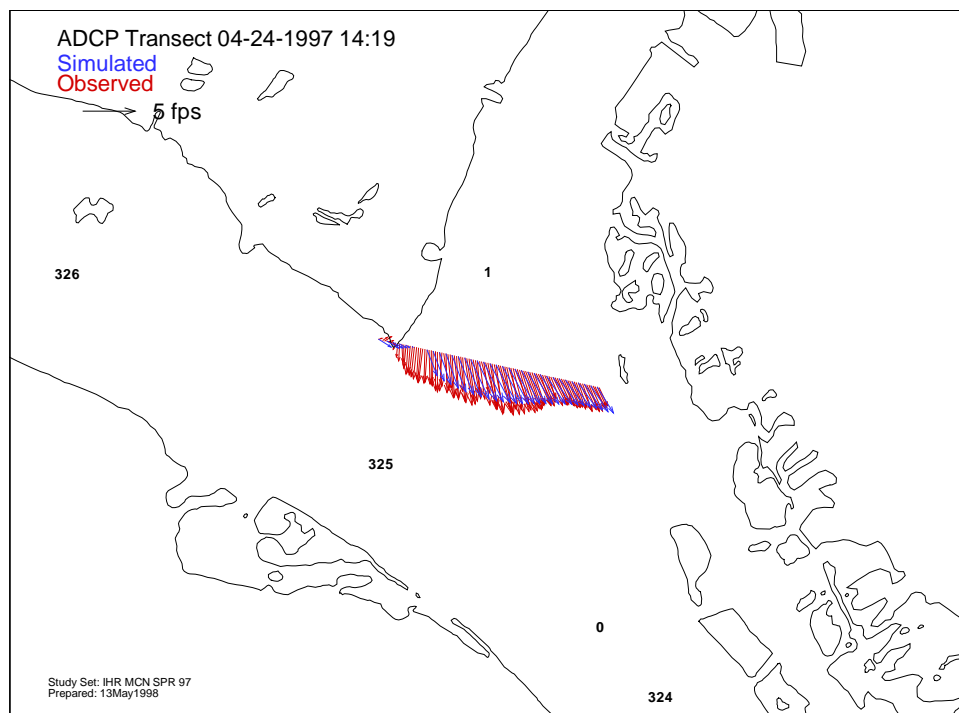
**Figure 30. Simulated and observed depth-averaged velocities near Snake River Mile 5 on 4-24-1997.**



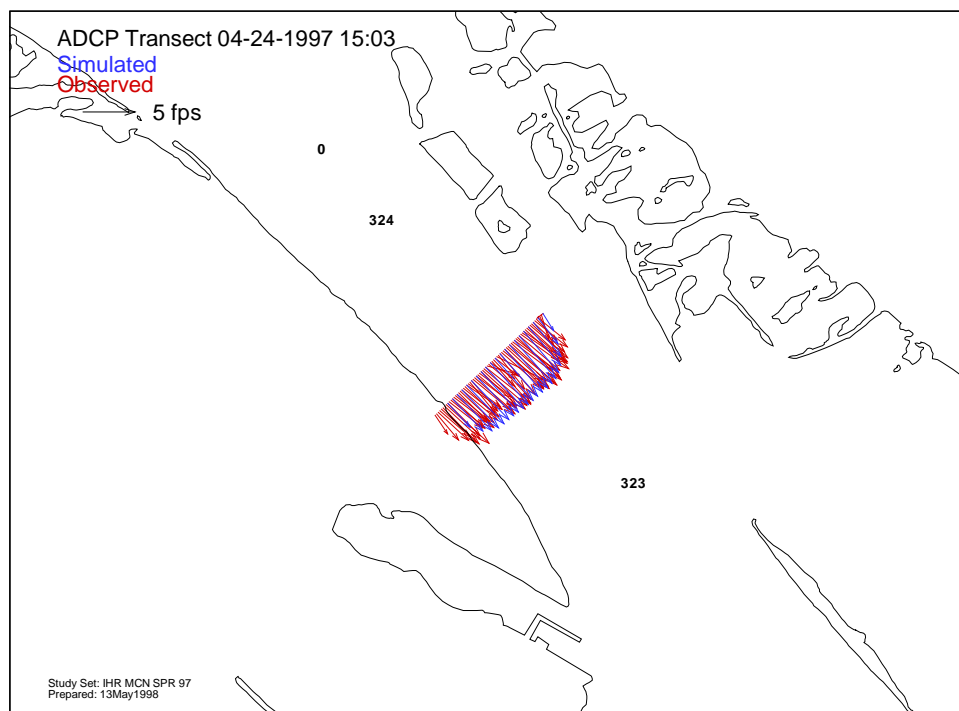
**Figure 31. Simulated and observed depth-averaged velocities near Snake River Mile 4.5 on 4-24-1997.**



**Figure 32. Simulated and observed depth-averaged velocities near Snake River Mile 2 on 4-24-1997.**

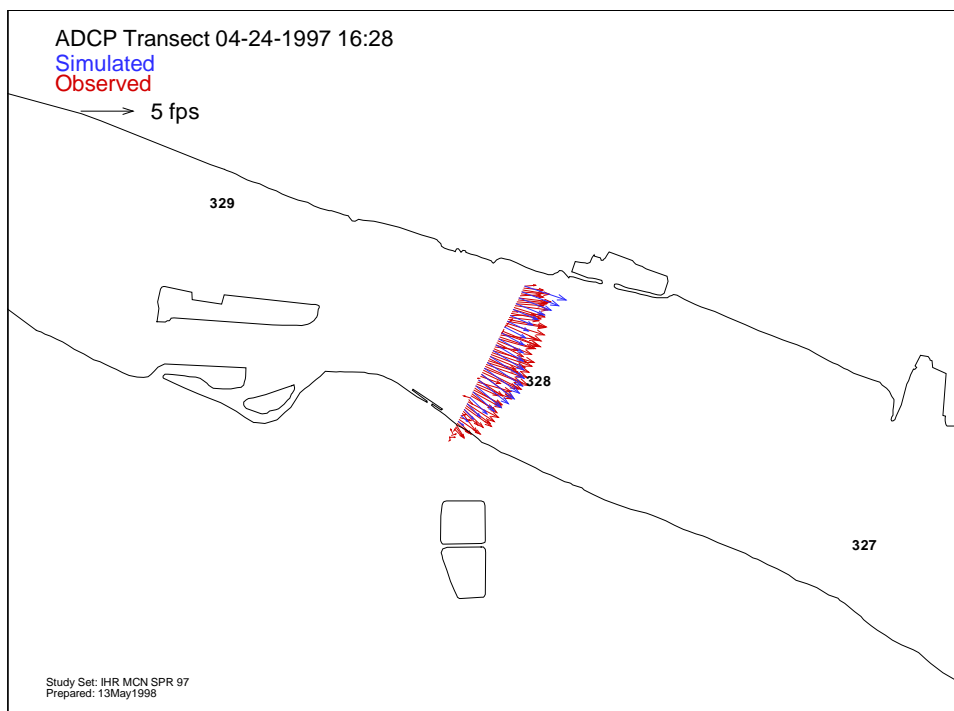


**Figure 33. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 4-24-1997.**

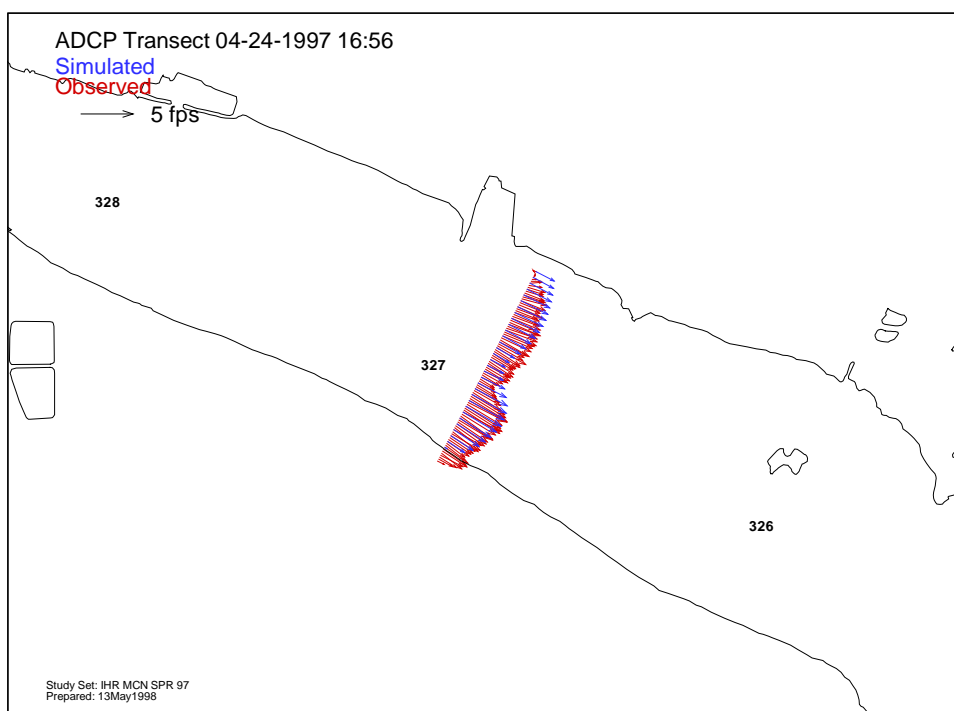


**Figure 34. Simulated and observed depth-averaged velocities near Columbia River Mile 323.5 on 4-24-1997.**

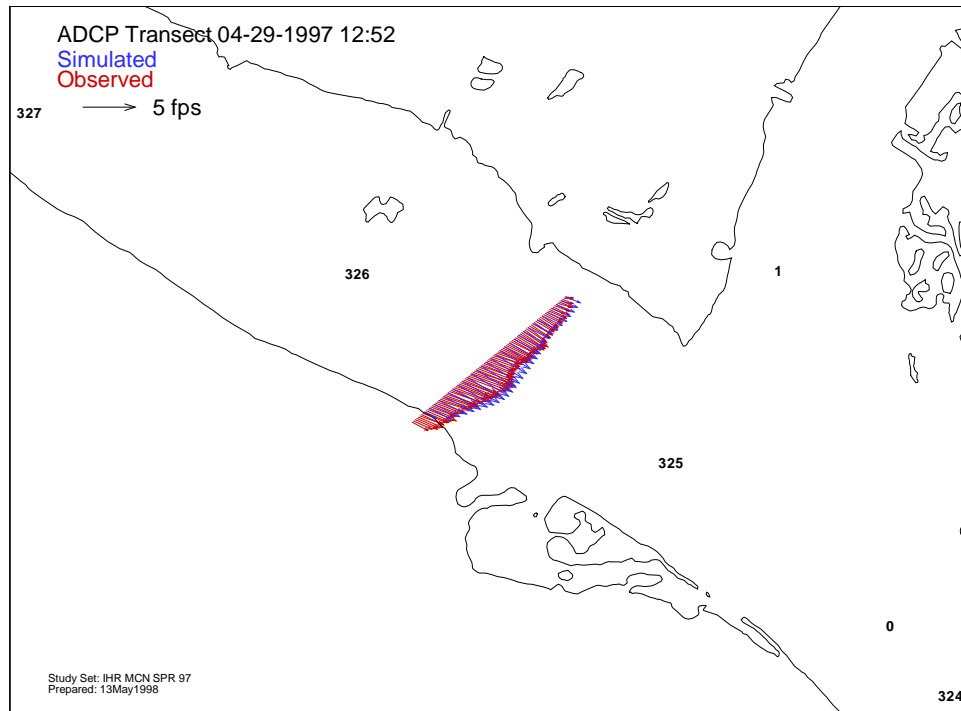




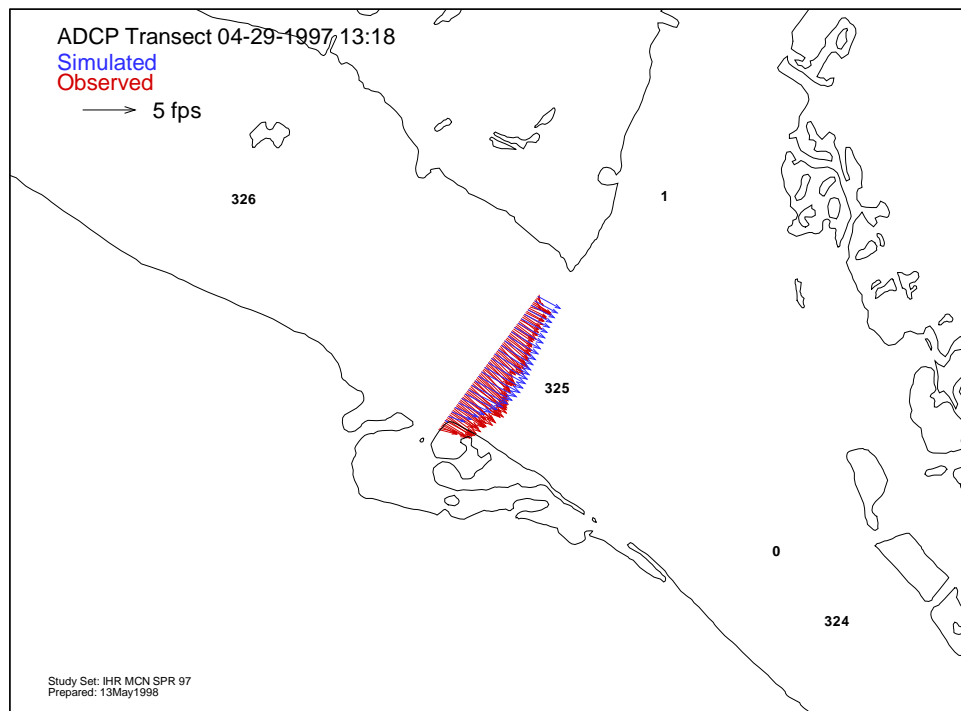
**Figure 35. Simulated and observed depth-averaged velocities near Columbia River Mile 328 on 4-24-1997.**



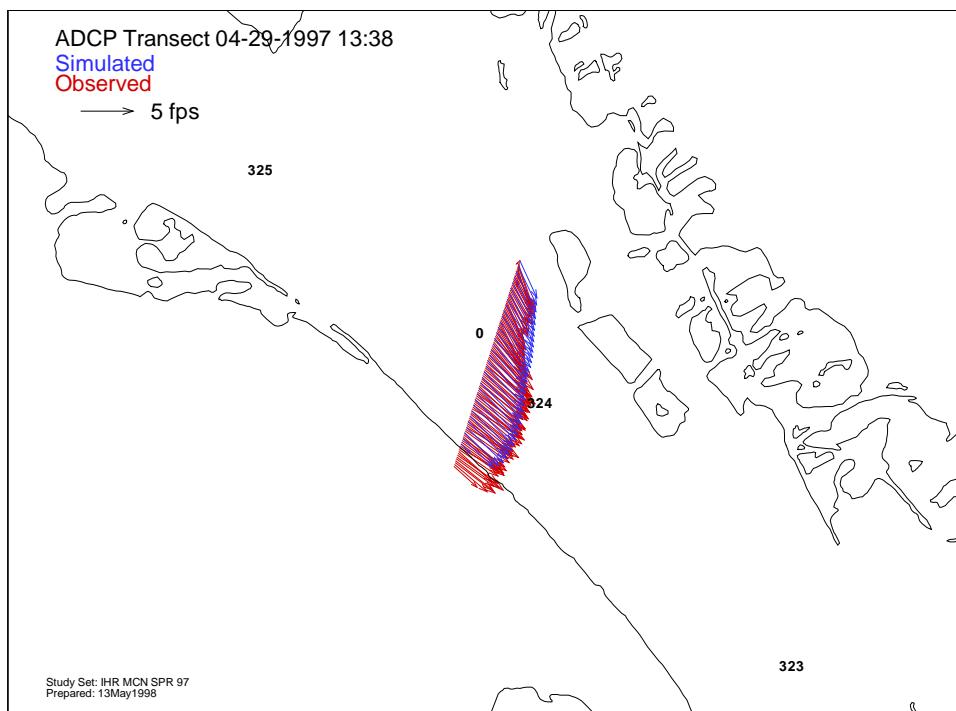
**Figure 36. Simulated and observed depth-averaged velocities near Columbia River Mile 327 on 4-24-1997.**



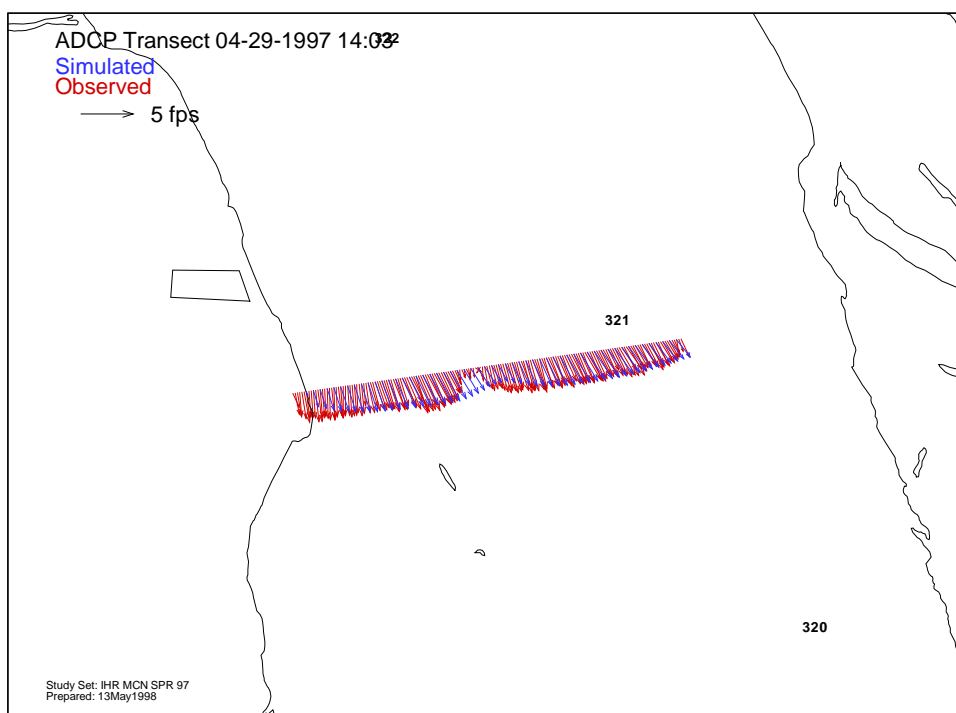
**Figure 37. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 4-29-1997.**



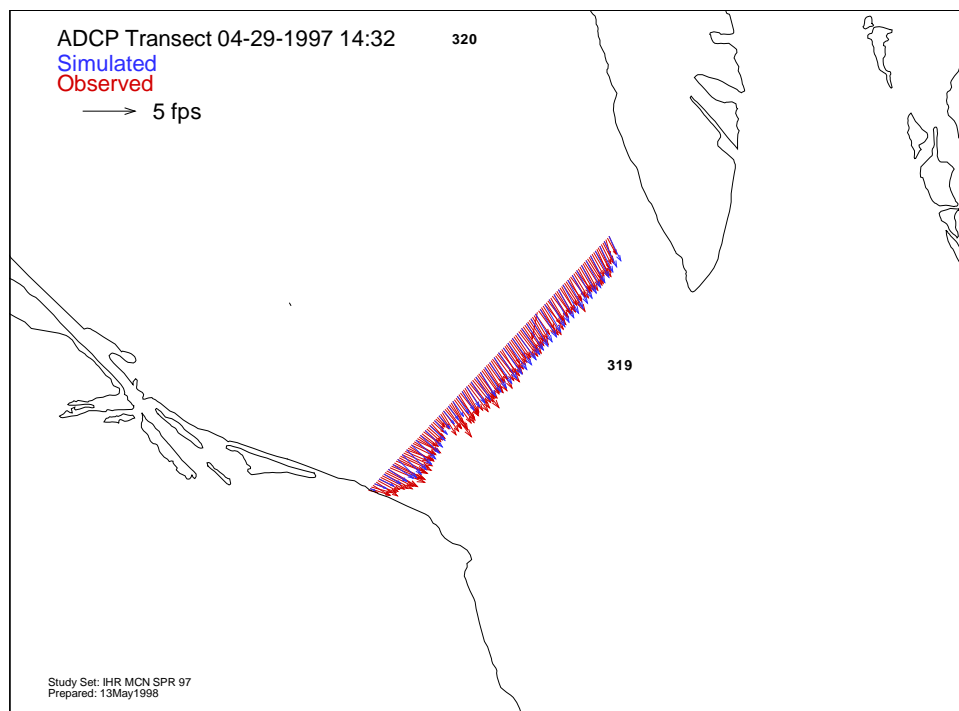
**Figure 38. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 4-29-1997.**



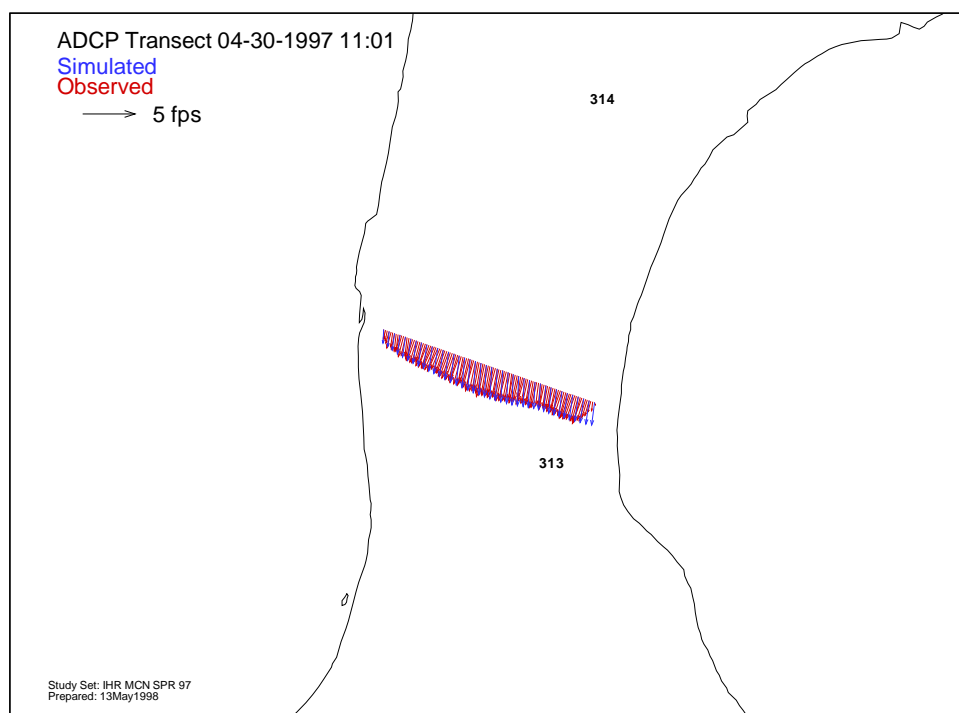
**Figure 39. Simulated and observed depth-averaged velocities at the confluence of the Columbia and Snake Rivers on 4-29-1997.**



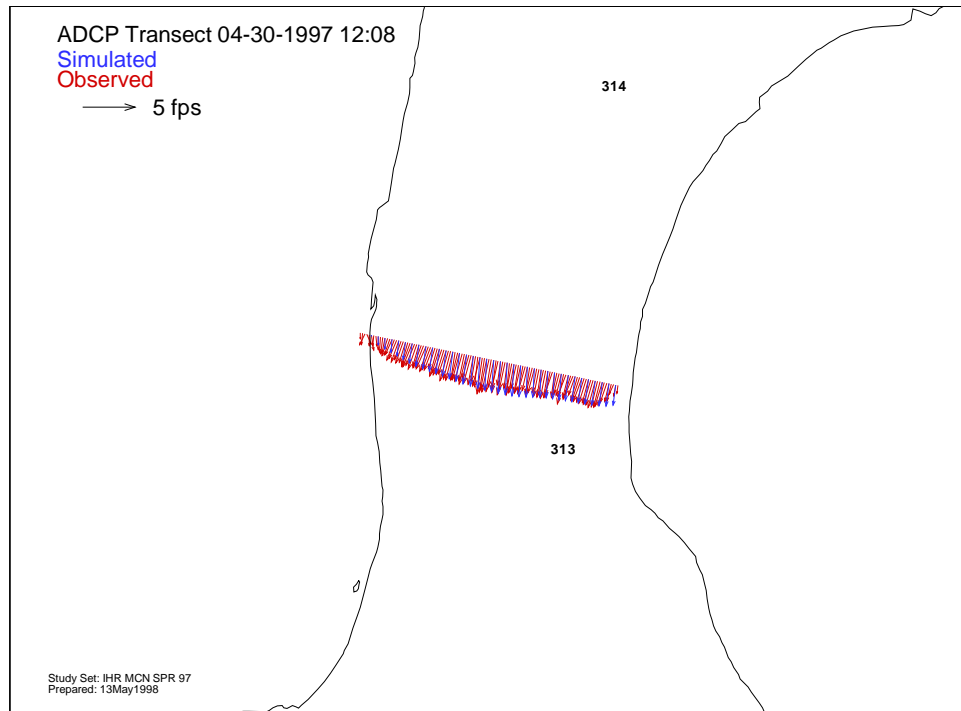
**Figure 40. Simulated and observed depth-averaged velocities near Columbia River Mile 321 on 4-29-1997.**



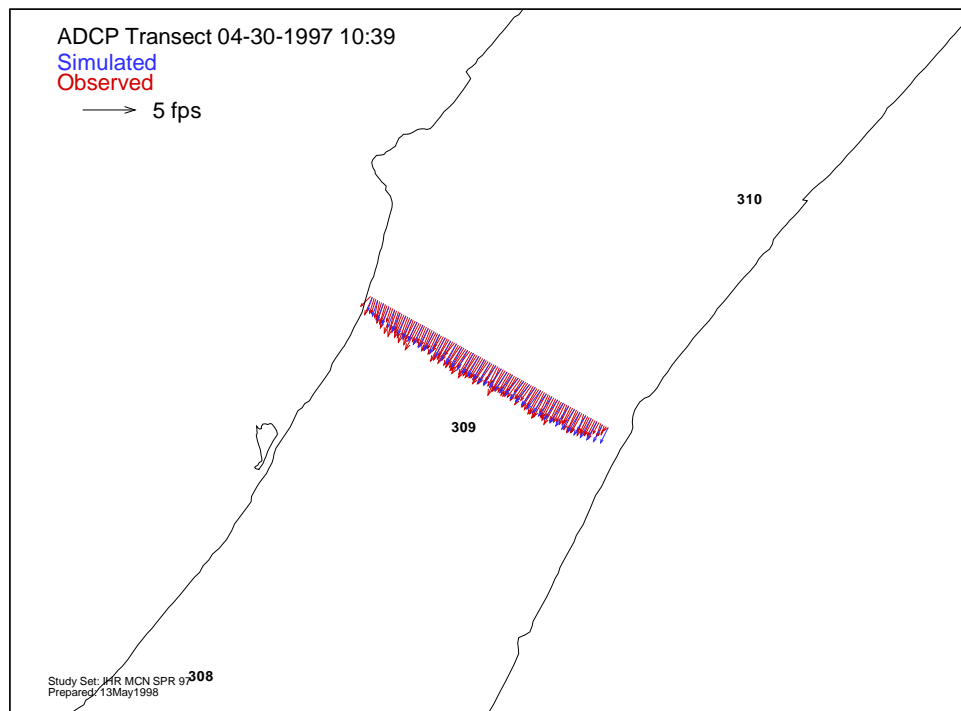
**Figure 41. Simulated and observed depth-averaged velocities near Columbia River Mile 319 on 4-29-1997.**



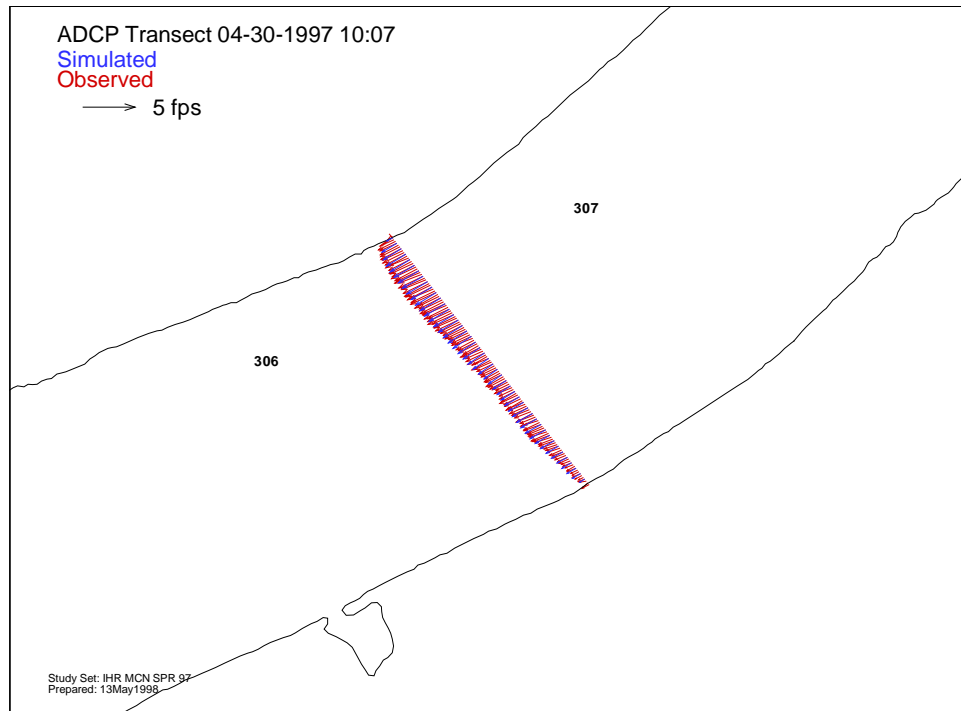
**Figure 42. Simulated and observed depth-averaged velocities at Wallula Gap near Columbia River Mile 313 on 4-30-1997.**



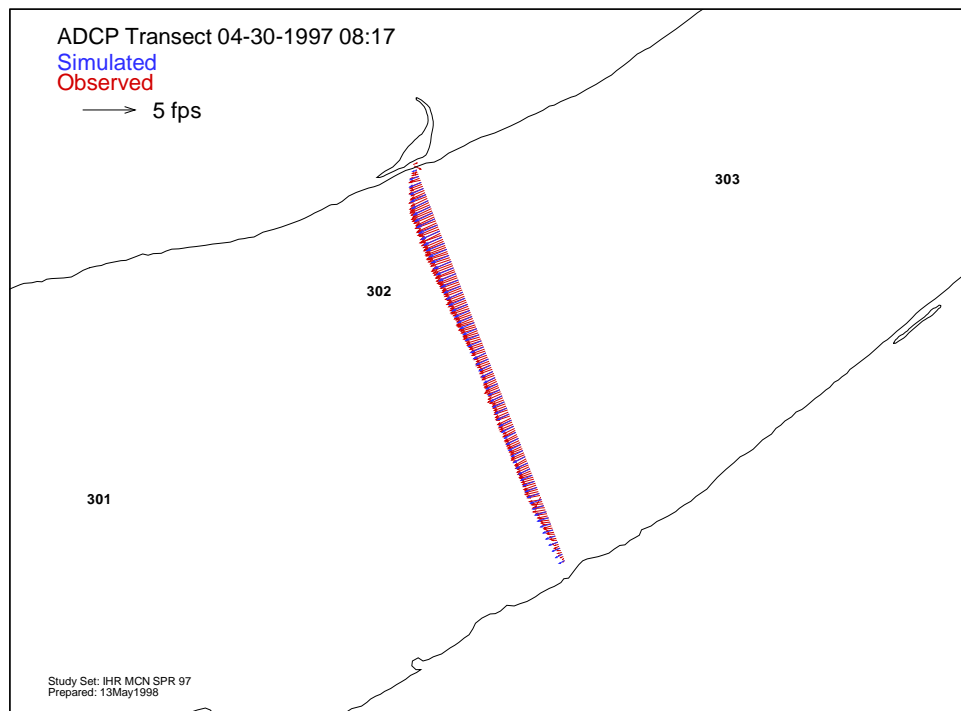
**Figure 43. Simulated and observed depth-averaged velocities at Wallula Gap near Columbia River Mile 313 on 4-30-1997.**



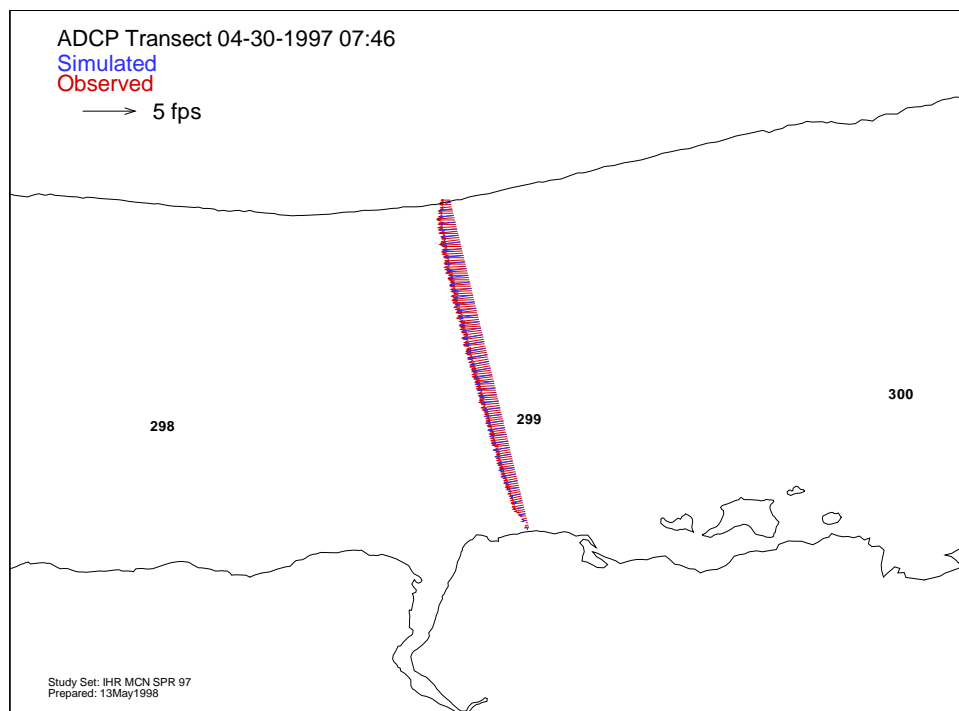
**Figure 44. Simulated and observed depth-averaged velocities near Columbia River Mile 309 on 4-30-1997.**



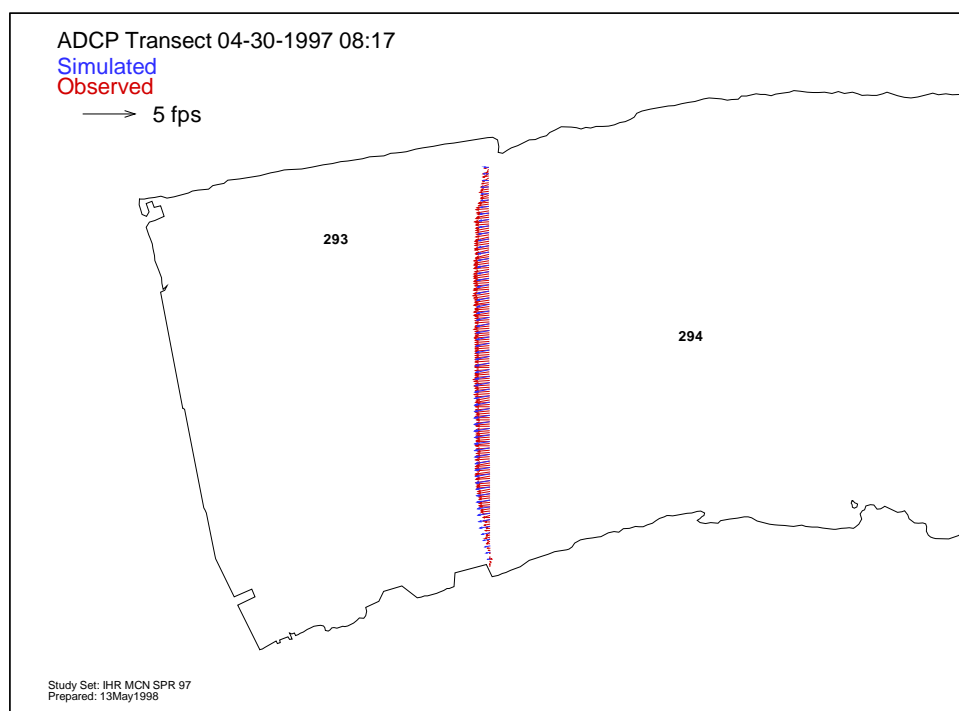
**Figure 45. Simulated and observed depth-averaged velocities near Columbia River Mile 305 on 4-30-1997.**



**Figure 46. Simulated and observed depth-averaged velocities near Columbia River Mile 302 on 4-30-1997.**



**Figure 47. Simulated and observed depth-averaged velocities near Columbia River Mile 299 on 4-30-1997.**



**Figure 48. Simulated and observed depth-averaged velocities at the McNary Dam forebay near Columbia River Mile 293.5 on 4-30-1997.**

### **1.3.4 Discussion**

The model tailwater calibration and verification showed good agreement with the Ice Harbor Tailwater gage over a wide range of flows. Differences in elevation were less than 0.5 ft. It is not certain why the model under predicts the elevation at times during the 1996 simulations, but performs well at higher stages during 1997. As noted above, this might be related to turbine unit operations.

The comparisons between the simulated velocities and those measured using the ADCP are generally good at the majority of transects. Adjusting the roughness coefficient distribution to better match the data was not warranted at this time because of the uncertainty in the ADCP coordinates.

## **1.4 Water Quality Calibration and Verification**

The model simulates the transport of the mass concentration of total dissolved gas (TDG) in water. Total dissolved gas is assumed to be composed of air in the following fractions: nitrogen (78.084%), oxygen (20.946%), argon (0.934%), and carbon dioxide (0.0320%). The conversion from total dissolved gas concentration to total pressure and/or saturation and vice versa is done using the relationships in Colt (1984) assuming that the TDG is in the air ratios given above. For the range of conditions simulated here  $\pm 5\%$  saturation corresponds to approximately  $\pm 1.5$  mg/l TDG concentration.

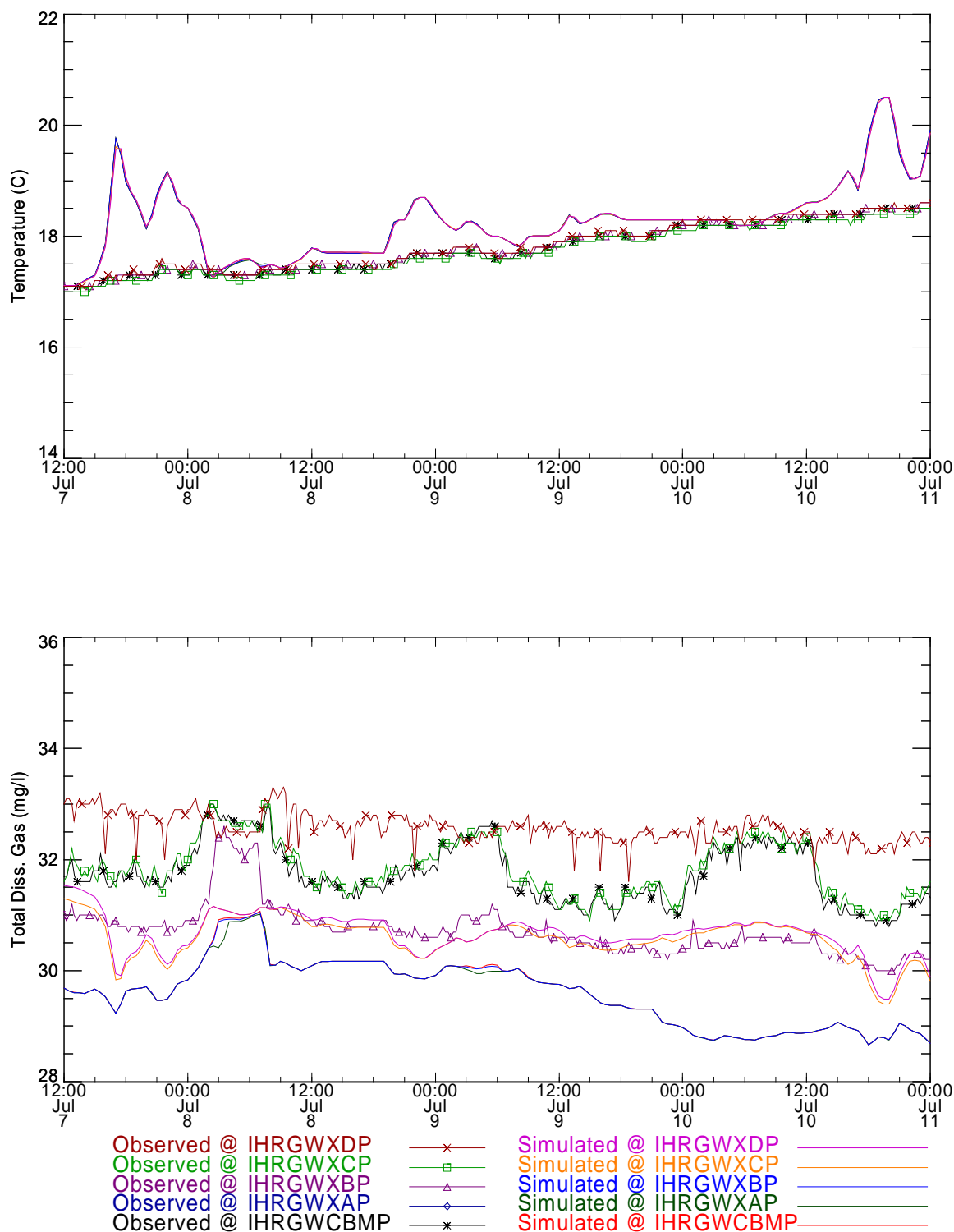
The principal model parameter that was varied in the water quality simulations was the lateral mixing coefficient. A spatially uniform and constant value of  $0.5 \text{ ft}^2/\text{s}$  was found to produce the best overall agreement with the field data. These simulations were all performed setting the surface gas exchange to zero. This provides a baseline with which to compare different parameterizations for gas exchange at the air-water interface.

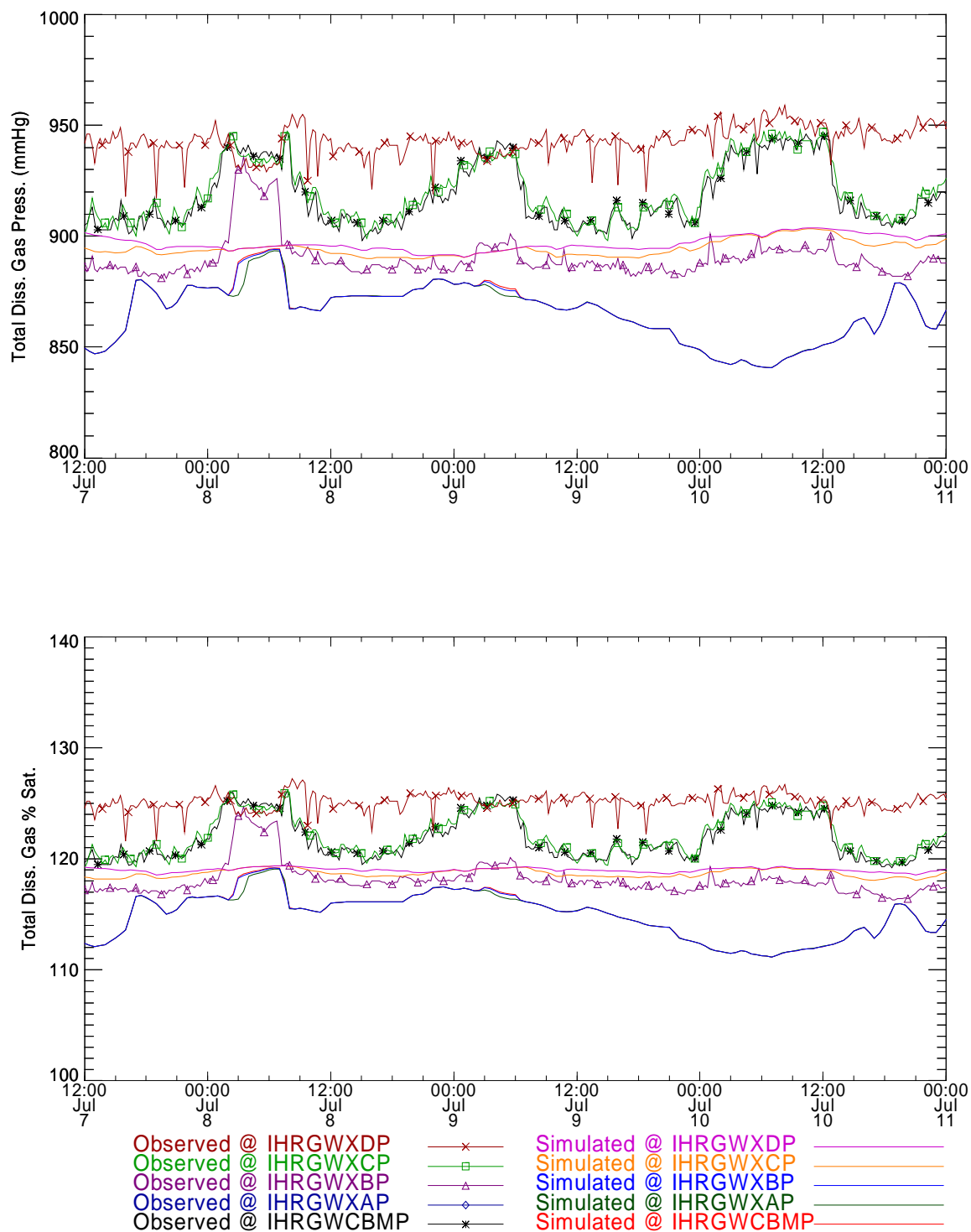


### ***1.4.1 1996 Summer Simulation***

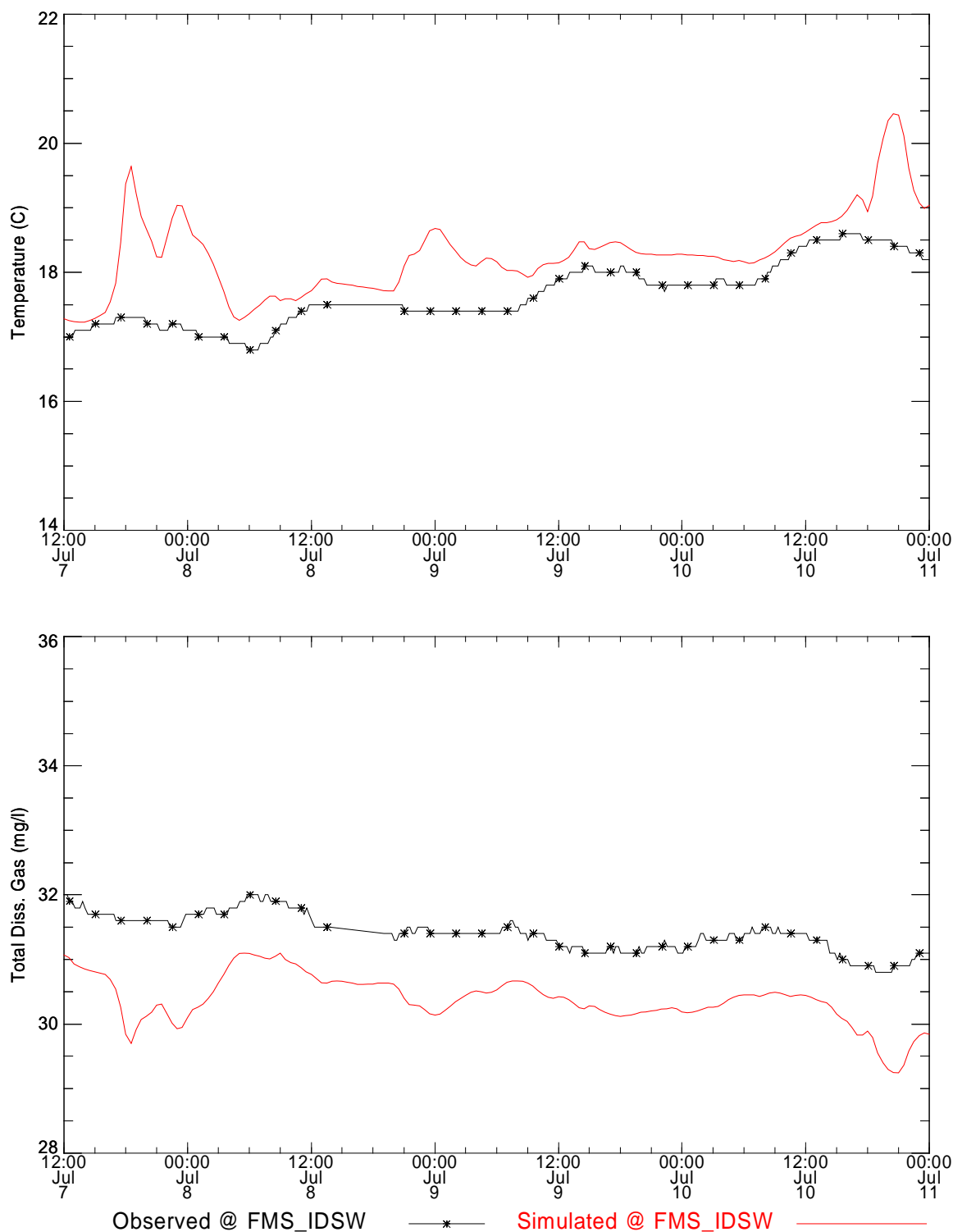
#### **Boundary Conditions using Ice Harbor Sourcing Function and Forebay Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS monitor are shown in the Figures below. This case is denoted as FMS-BC in the figure captions.

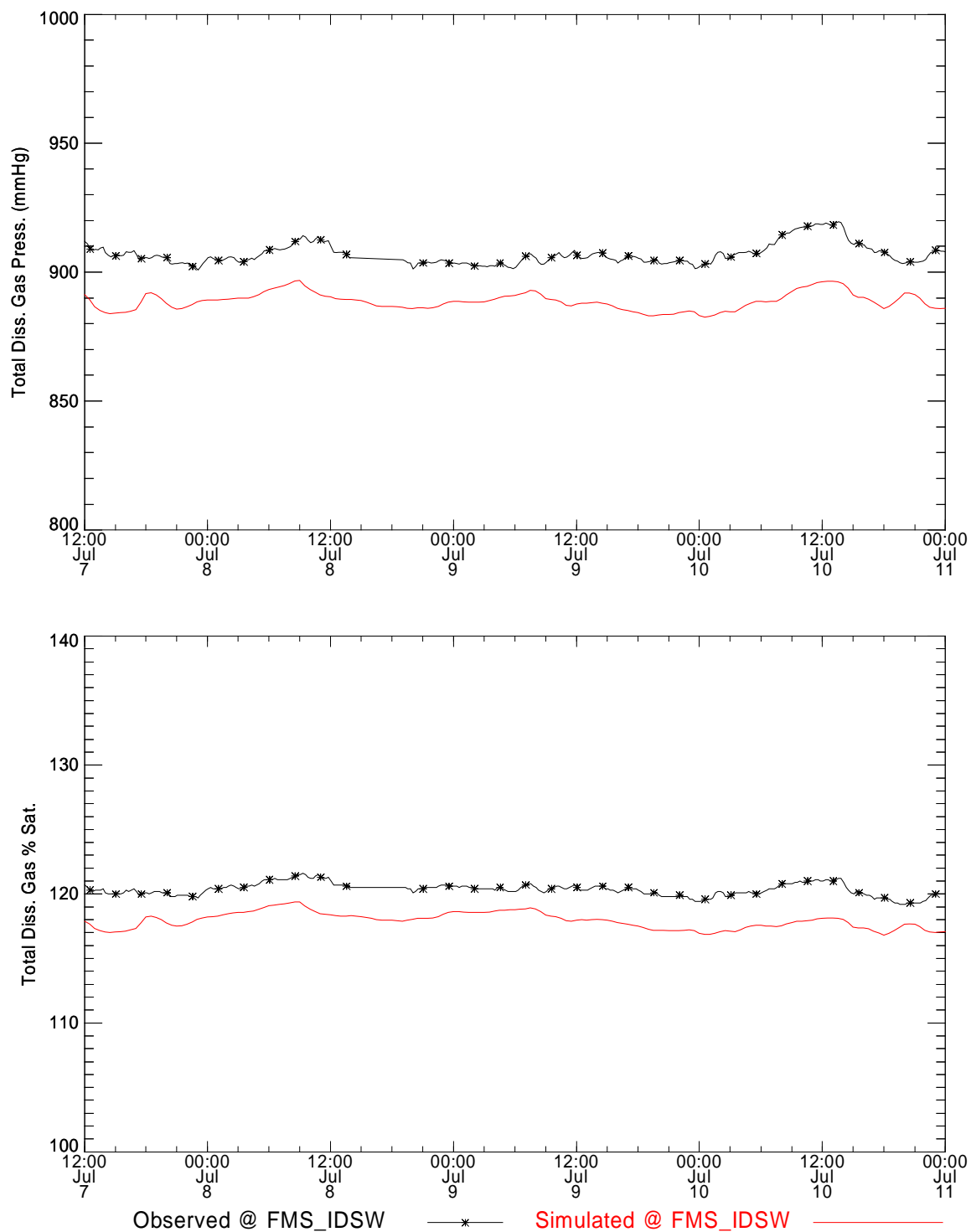




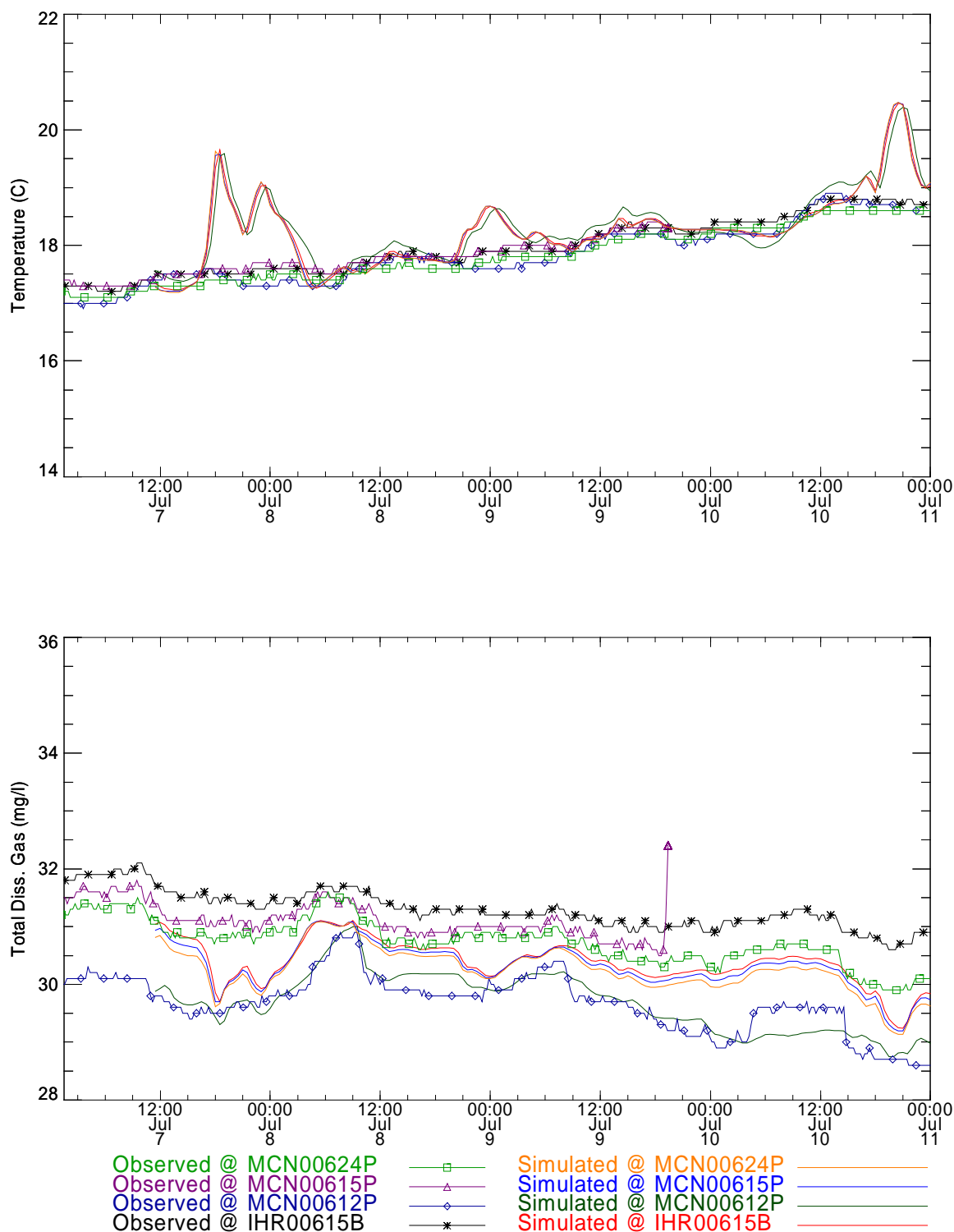
**Figure 50. Total dissolved gas pressure and saturation time series comparisons near Ice Harbor Dam for the Summer 1996 pool study (FMS-BC).**



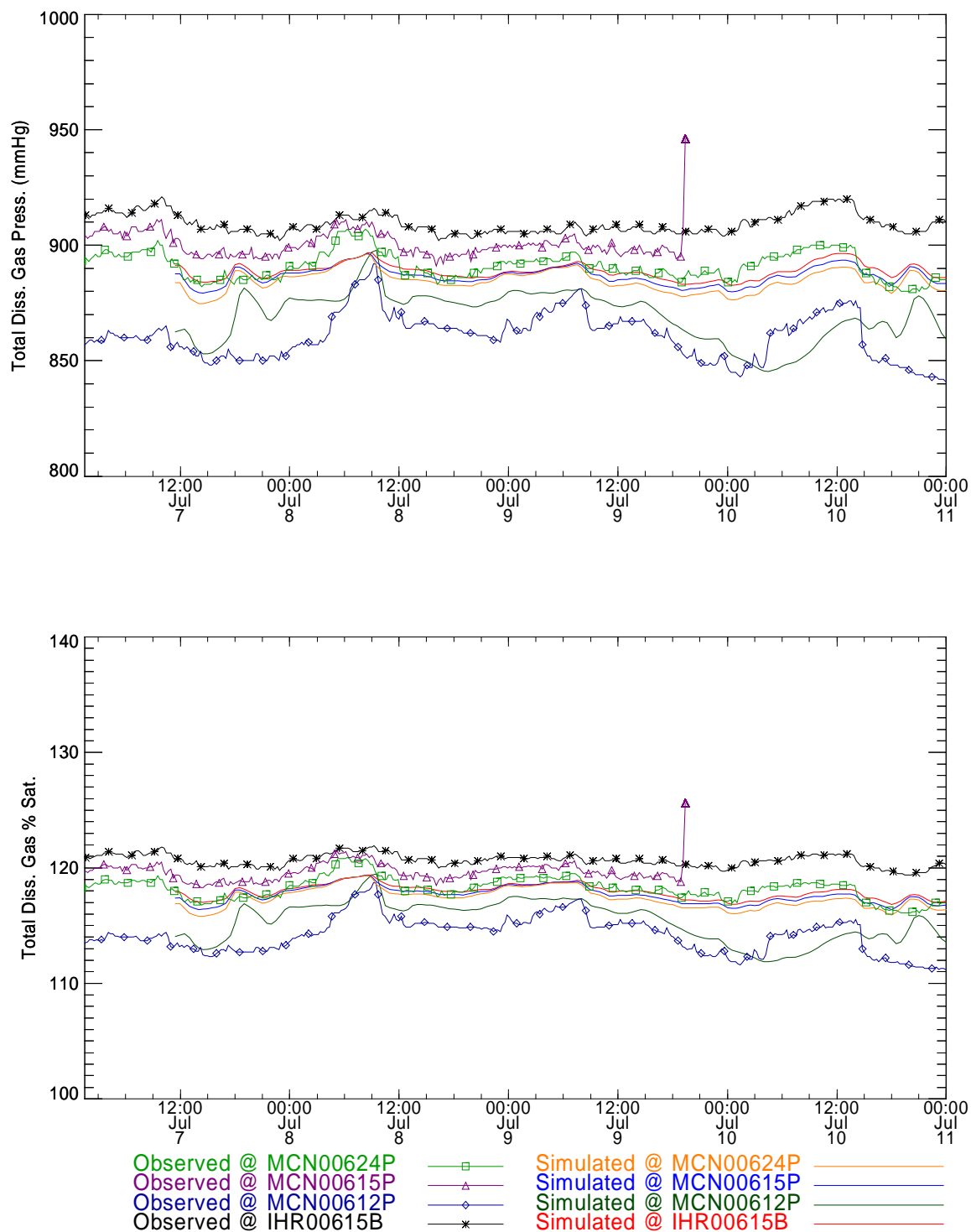
**Figure 51. Temperature and total dissolved gas time series comparisons near the Ice Harbor Fixed Monitor for the Summer 1996 pool study (FMS-BC).**



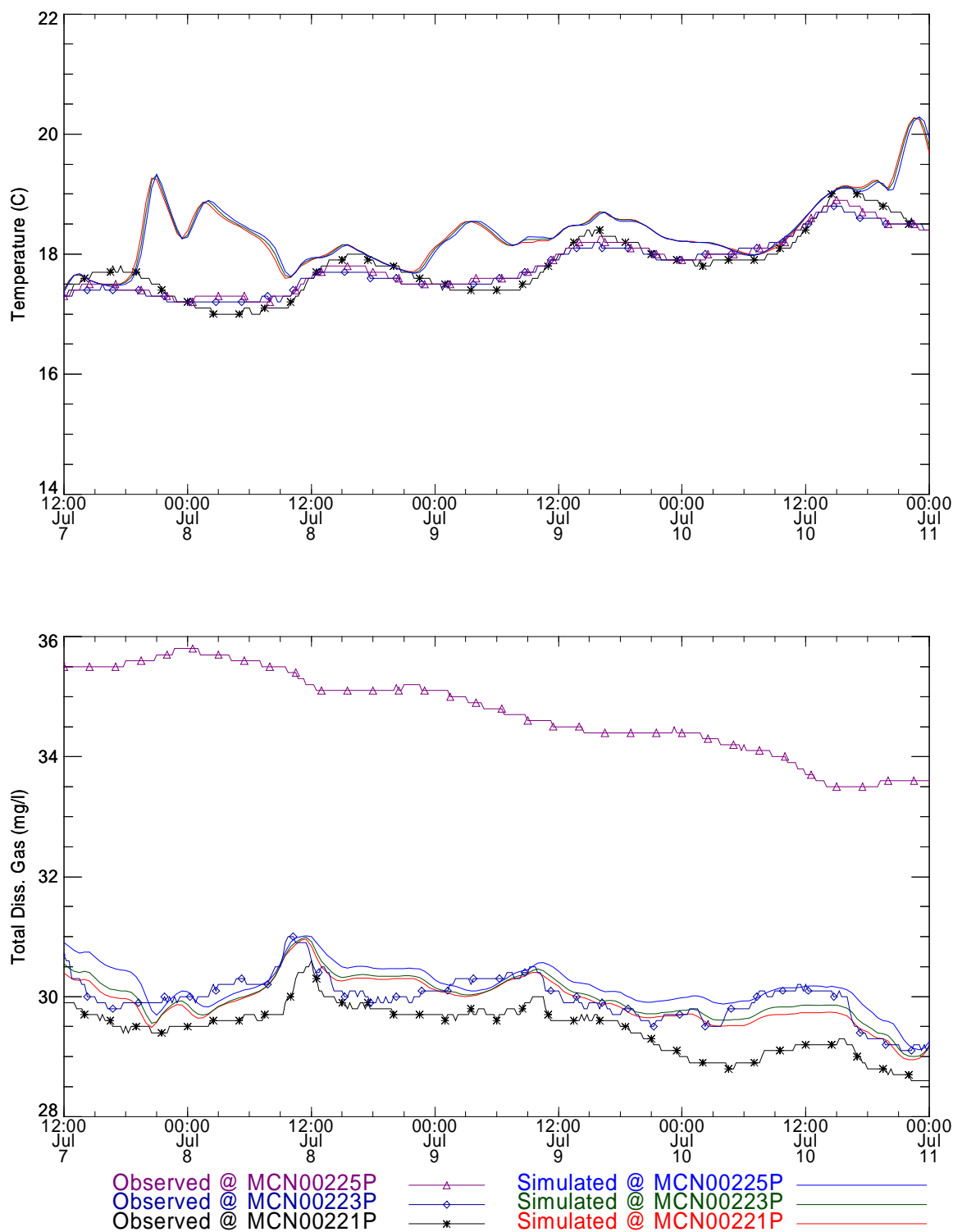
**Figure 52. Total dissolved gas time series comparisons near the Ice Harbor Fixed Monitor for the Summer 1996 pool study (FMS-BC).**



**Figure 53. Temperature and total dissolved gas time series comparisons near Snake River Mile 6.1 for the Summer 1996 pool study (FMS-BC).**

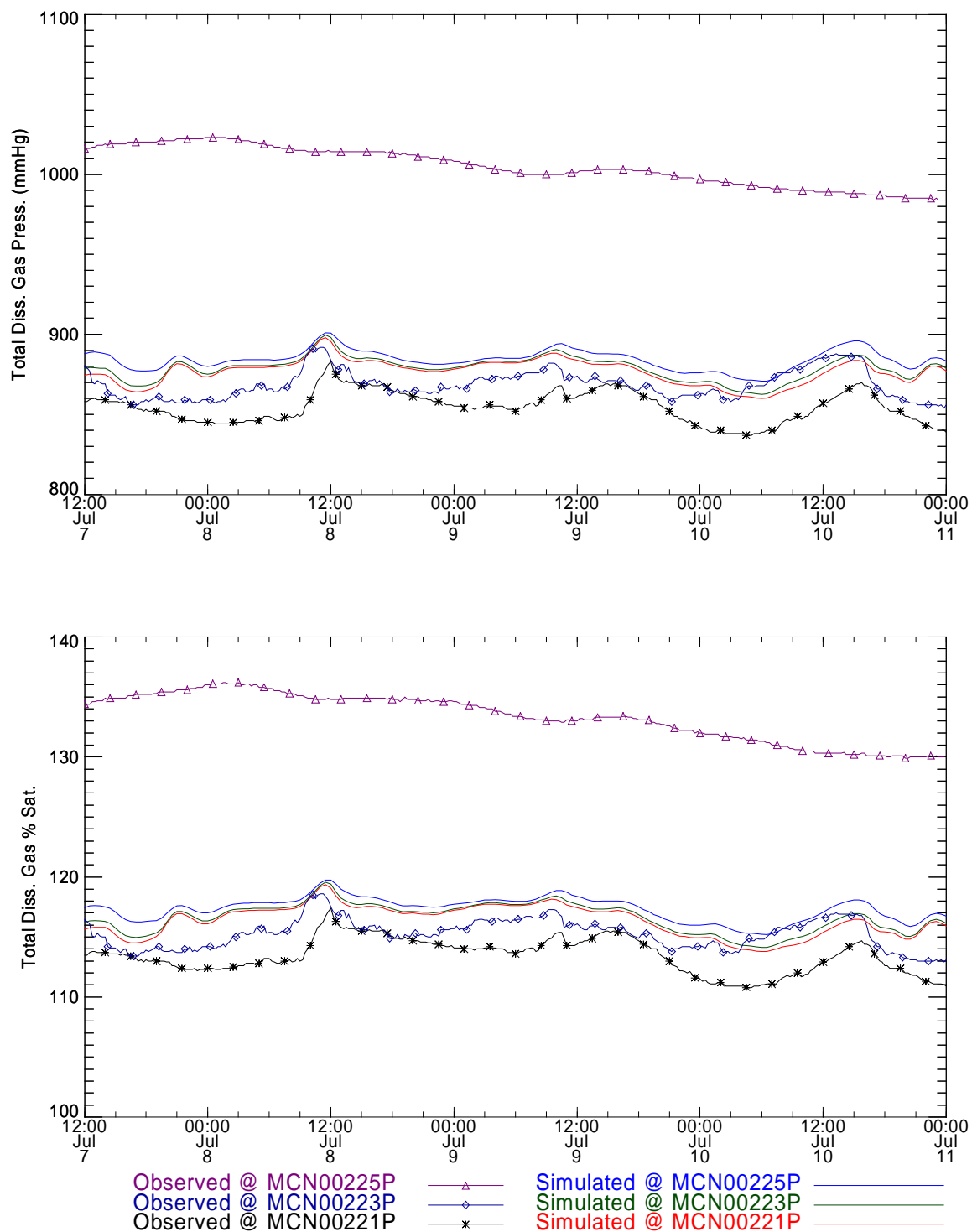


**Figure 54. Total dissolved gas time series comparisons near Snake River Mile 6.1 for the Summer 1996 pool study (FMS-BC).**

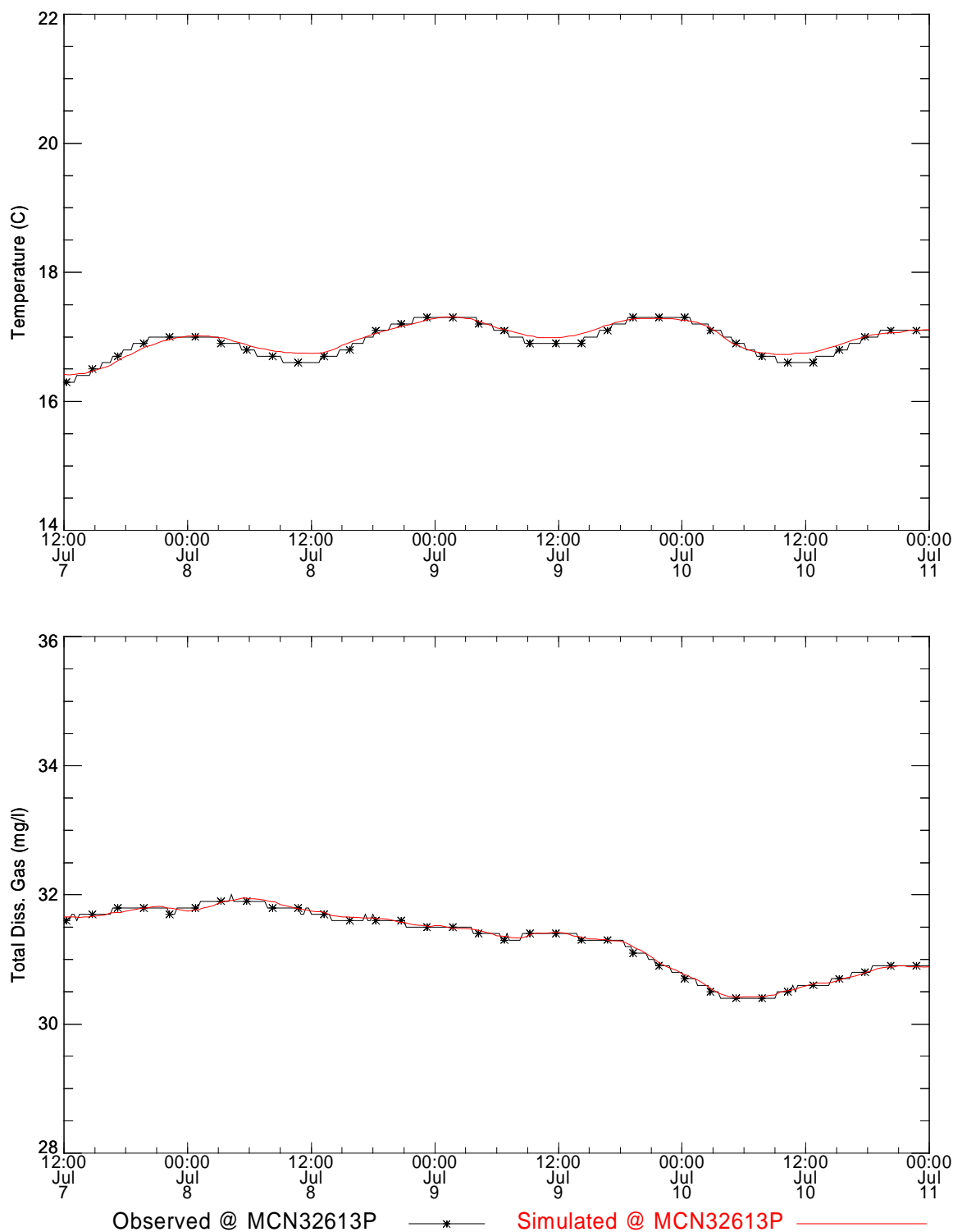


**Figure 55. Temperature and total dissolved gas time series comparisons near Snake River Mile 2.2 for the Summer 1996 pool study (FMS-BC).**

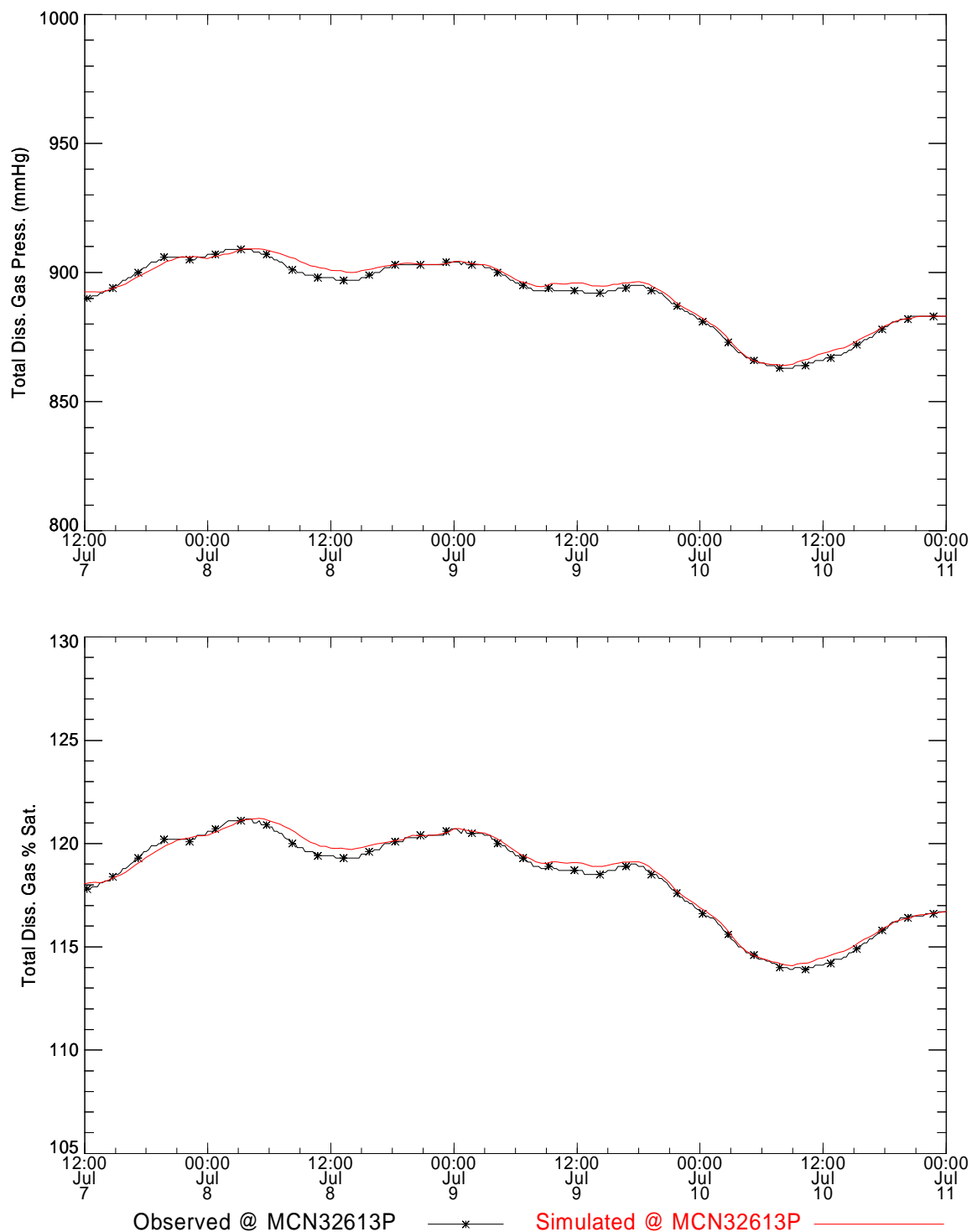




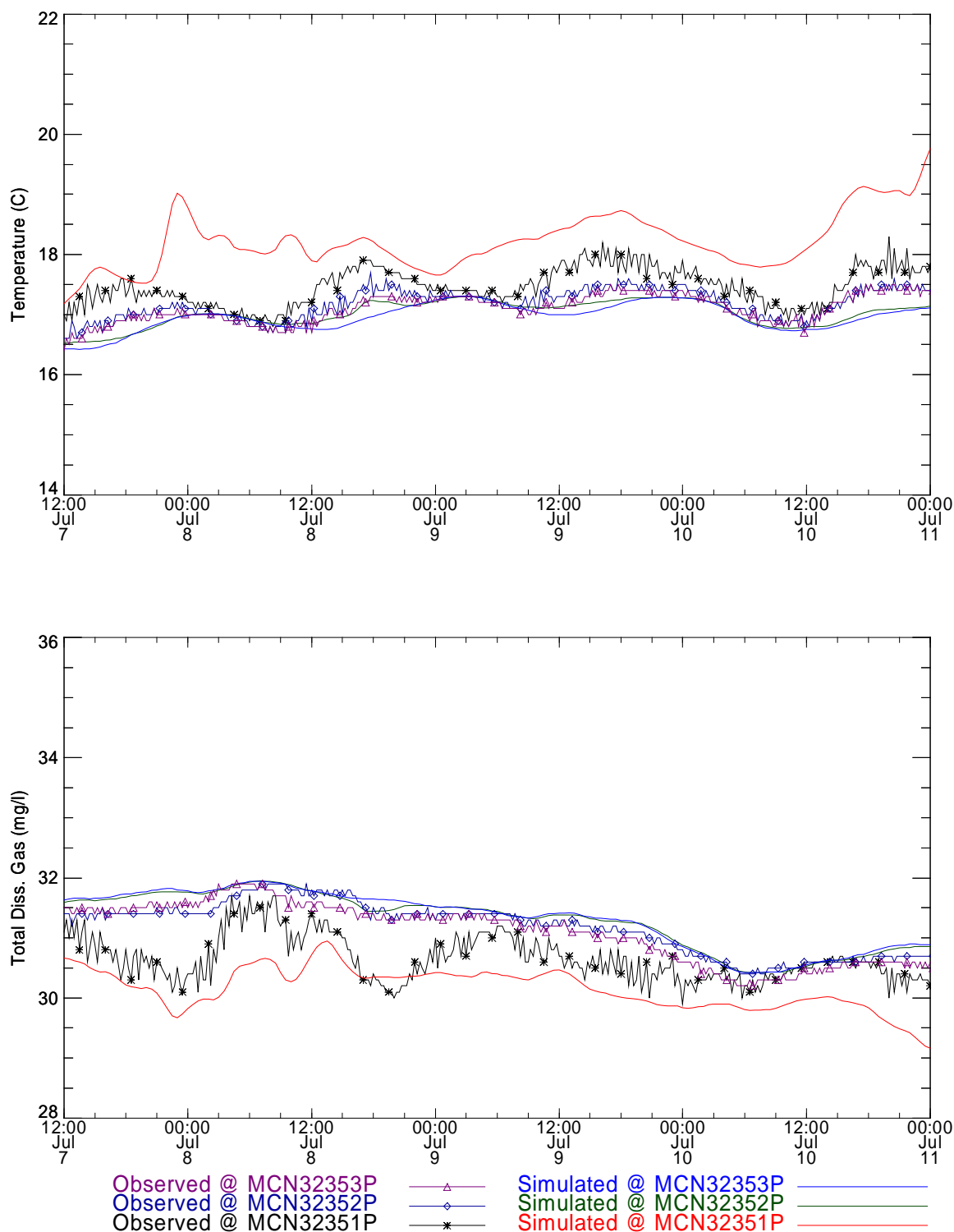
**Figure 56. Total dissolved gas time series comparisons near Snake River Mile 2.2 for the Summer 1996 pool study (FMS-BC).**



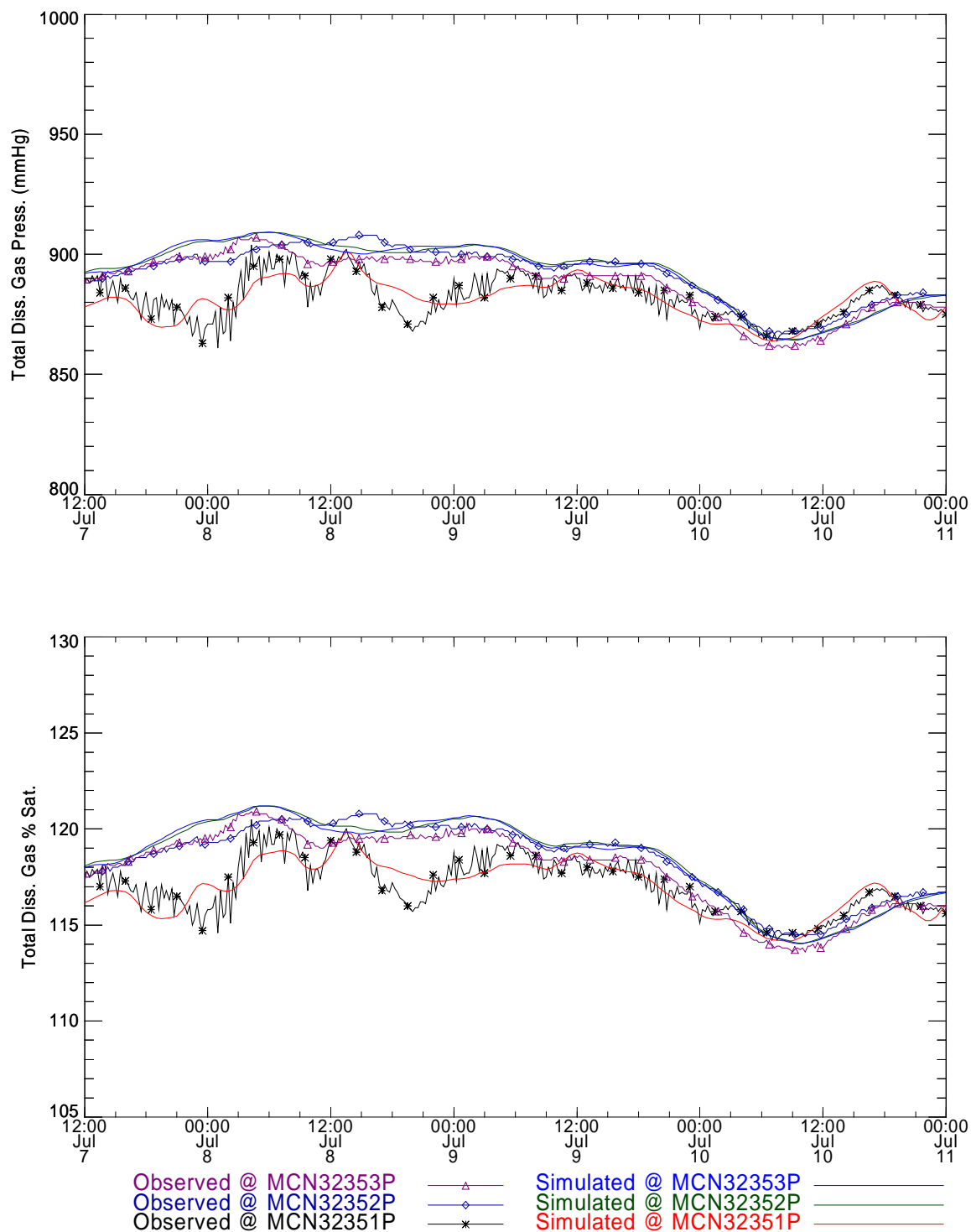
**Figure 57. Temperature and total dissolved gas time series comparisons near Columbia River Mile 326 for the Summer 1996 pool study (FMS-BC).**



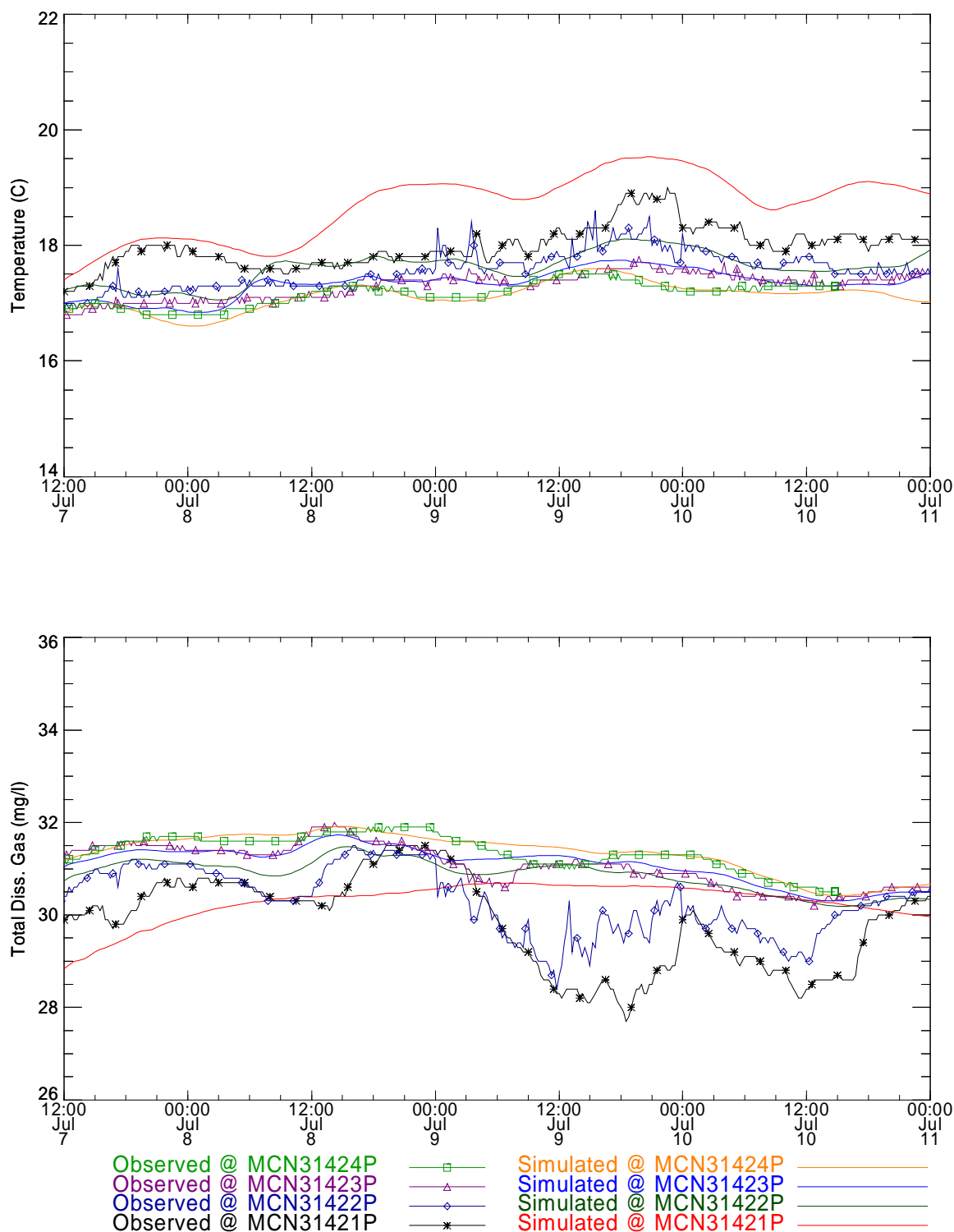
**Figure 58. Total dissolved gas time series comparisons near Columbia River Mile 326 for the Summer 1996 pool study (FMS-BC).**



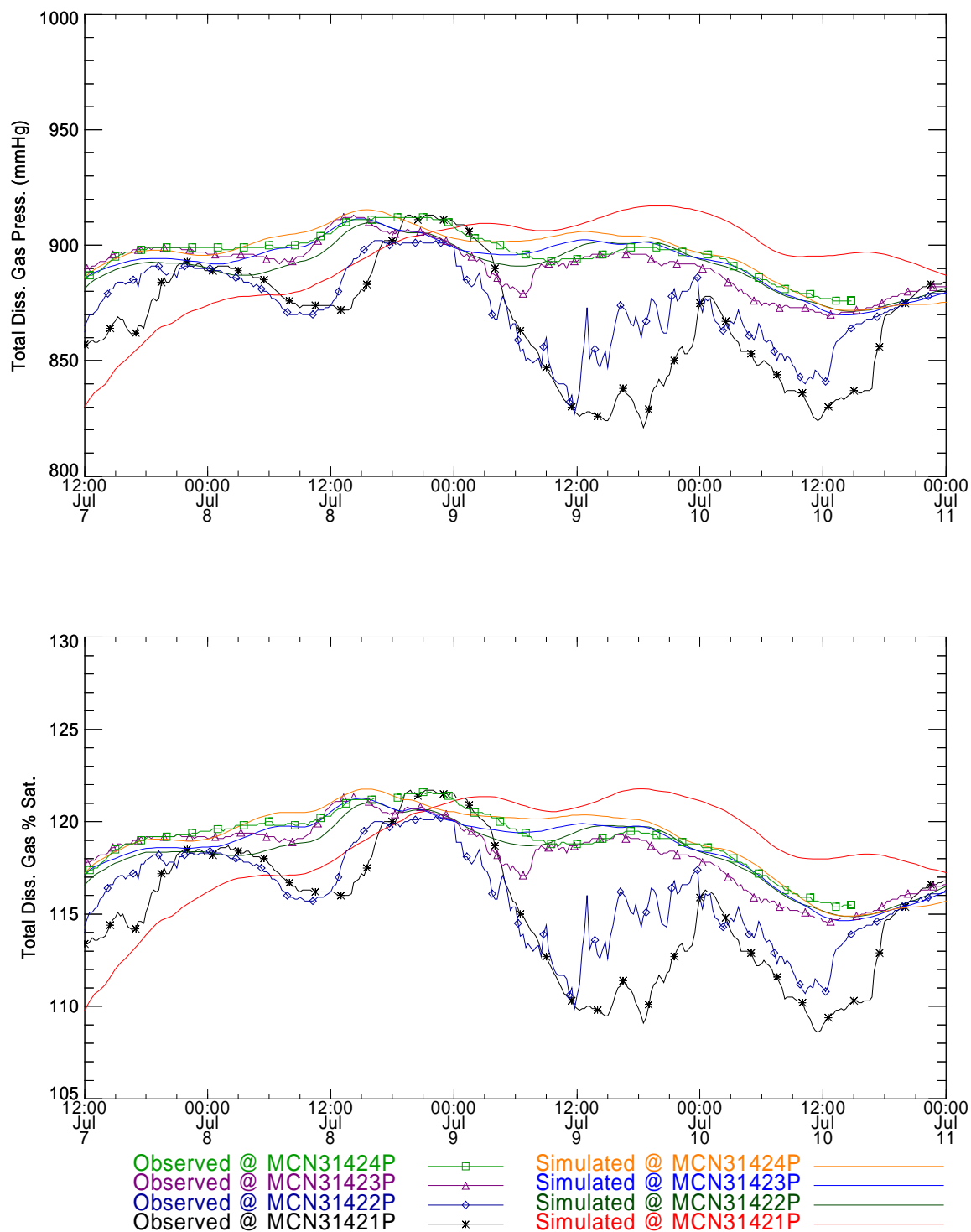
**Figure 59. Temperature and total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Summer 1996 pool study (FMS-BC).**



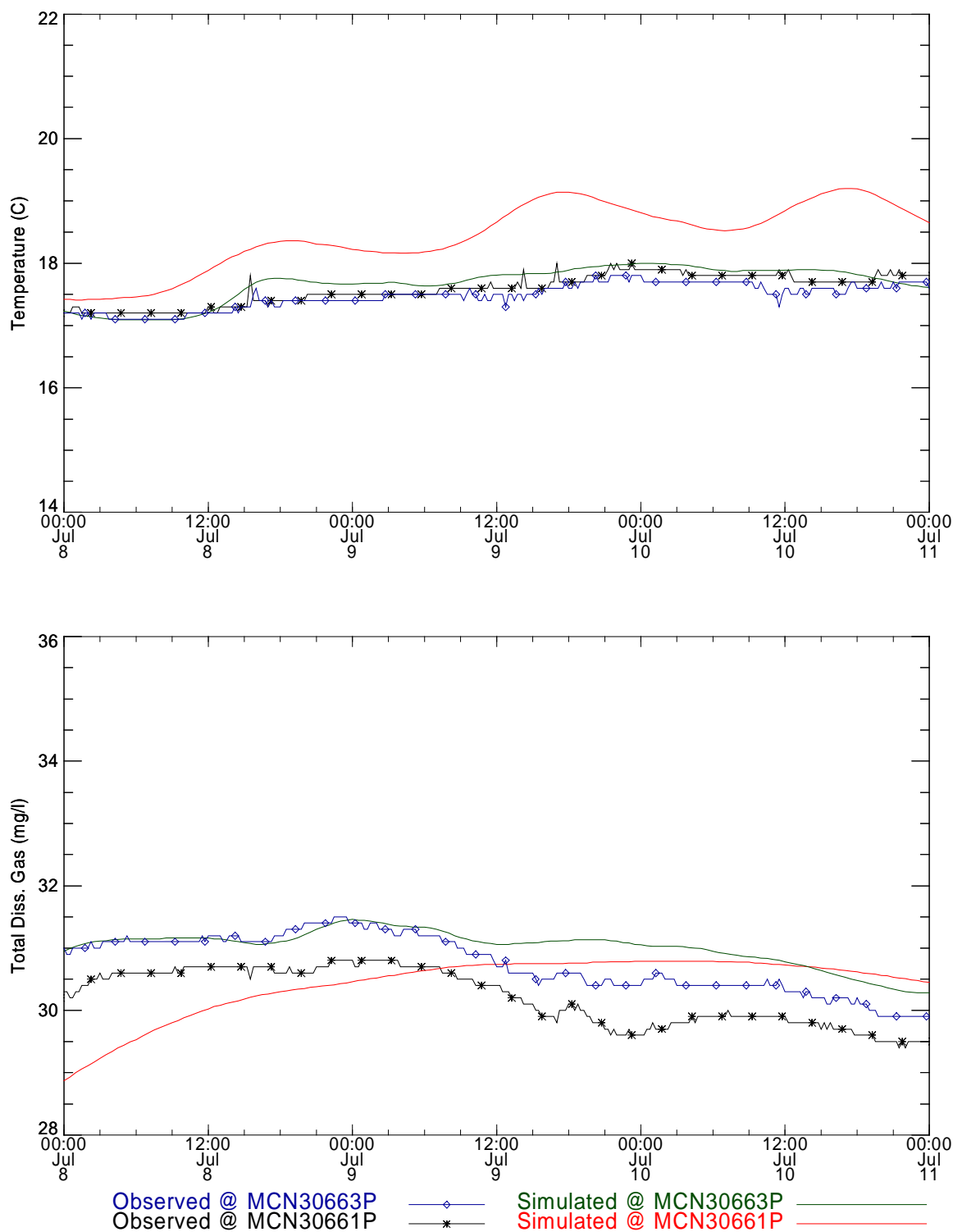
**Figure 60. Total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Summer 1996 pool study (FMS-BC).**



**Figure 61. Temperature and total dissolved gas time series comparisons near Columbia River Mile 314 for the Summer 1996 pool study (FMS-BC).**

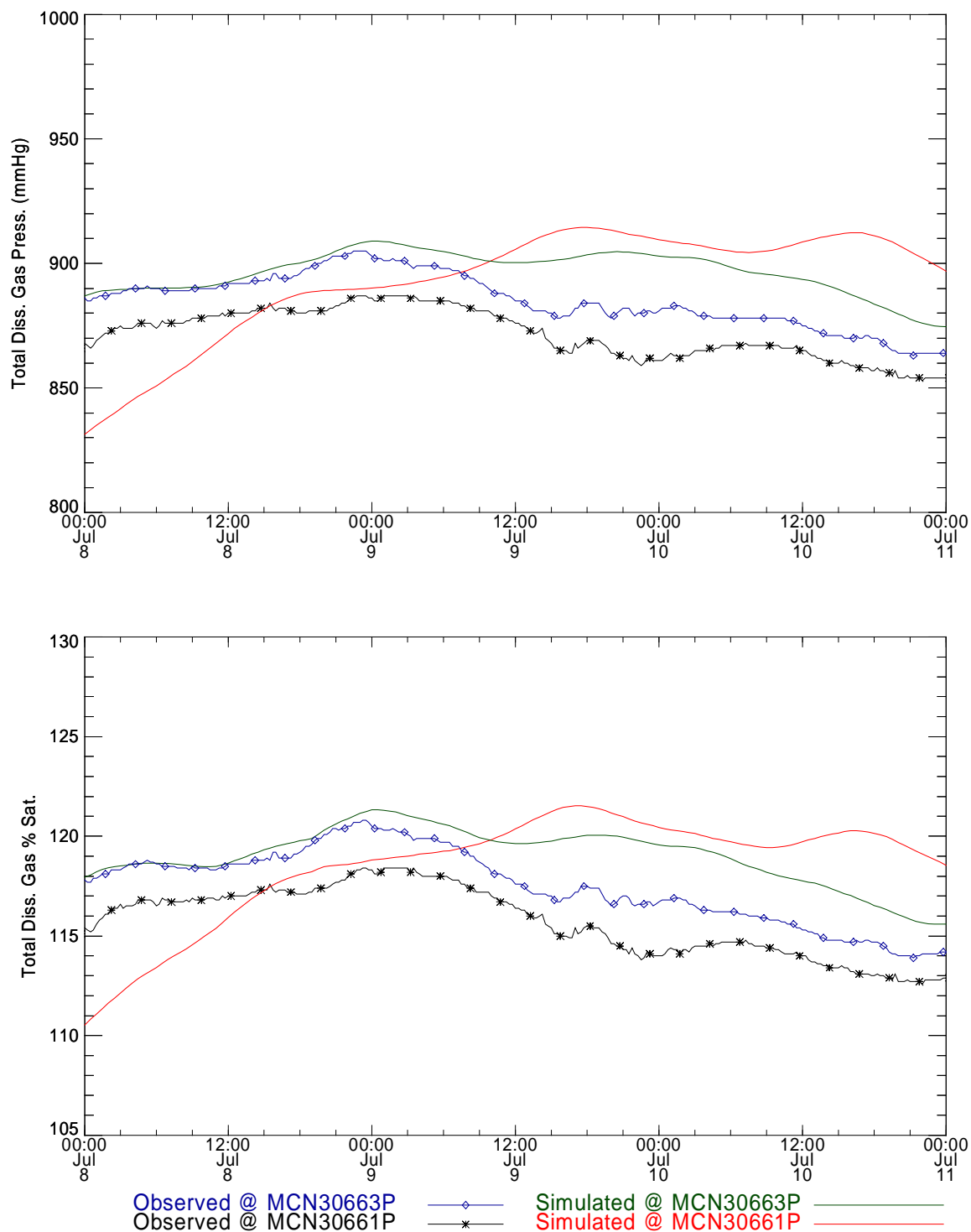


**Figure 62. Total dissolved gas time series comparisons near Columbia River Mile 314 for the Summer 1996 pool study (FMS-BC).**

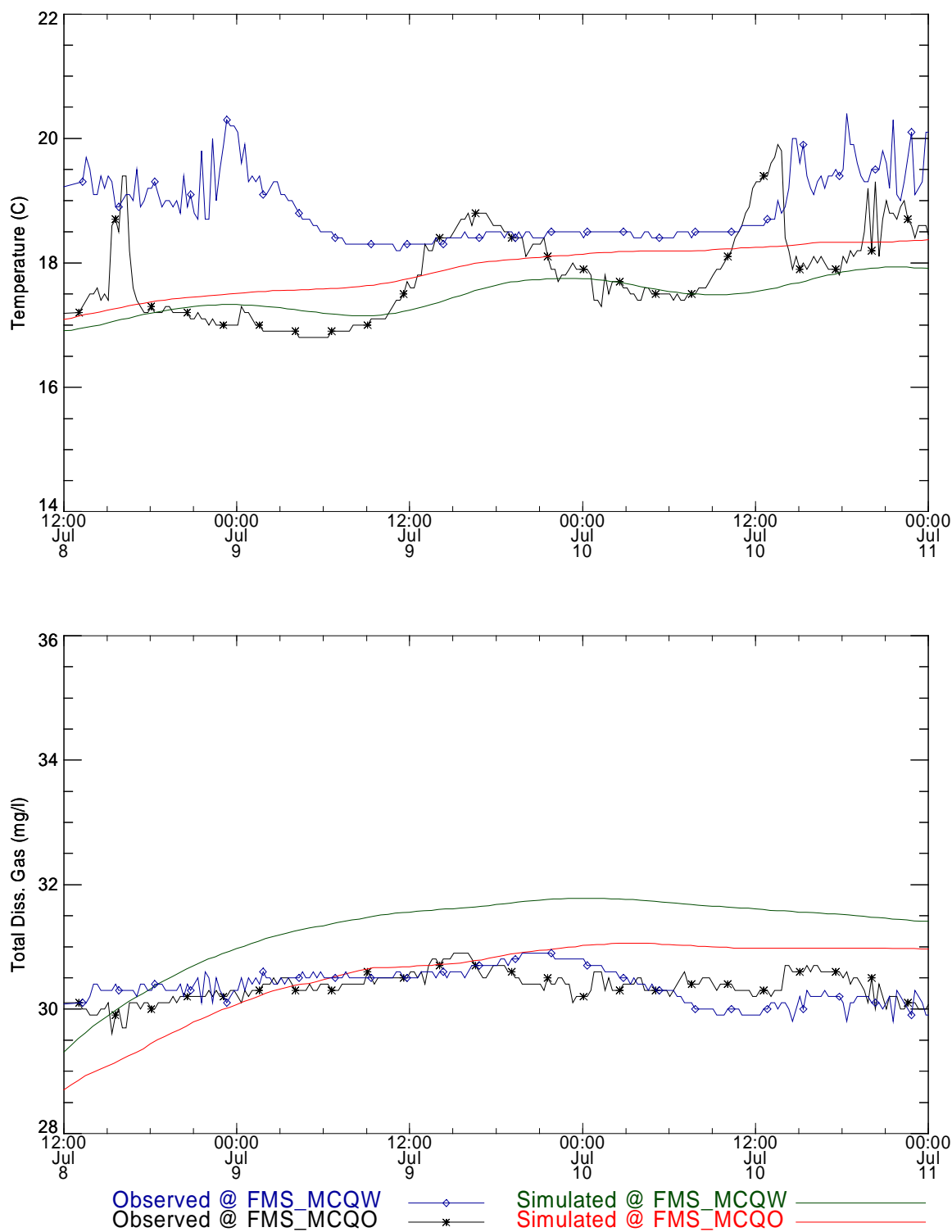


**Figure 63. Temperature and total dissolved gas time series comparisons near Columbia River Mile 306 for the Summer 1996 pool study (FMS-BC).**

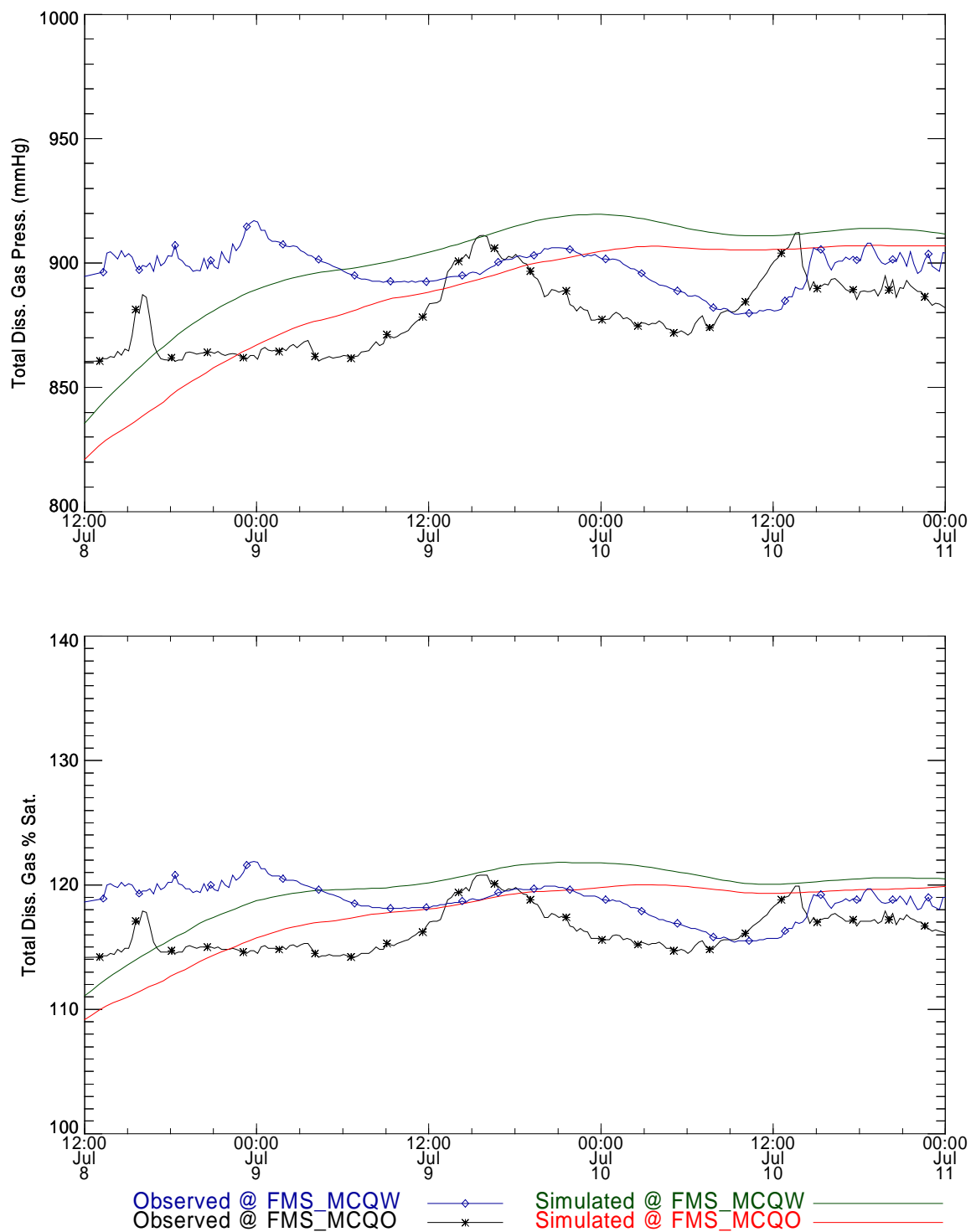




**Figure 64. Total dissolved gas time series comparisons near Columbia River Mile 306 for the Summer 1996 pool study (FMS-BC).**



**Figure 65. Temperature and total dissolved gas time series comparisons at the McNary Fixed Monitor for the Summer 1996 pool study (FMS-BC).**



**Figure 66. Total dissolved gas time series comparisons at the McNary Fixed Monitor for the Summer 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
IHRGWXBP	17.73	18.14	0.47	0.73	0.64
IHRGWCBMP	17.69	18.14	0.47	0.73	0.67
IHRGWXCP	17.65	18.13	0.47	0.73	0.69
IHRGWXDP	17.75	18.13	0.47	0.72	0.63
Concentration (mg/l)					
IHRGWXBP	30.77	29.63	0.45	0.58	1.19
IHRGWCBMP	31.79	29.64	0.53	0.58	2.23
IHRGWXCP	31.88	30.68	0.51	0.44	1.27
IHRGWXDP	32.65	30.77	0.35	0.44	1.92
Gas Pressure (mmHg)					
IHRGWXBP	889.88	864.81	8.94	12.85	28.23
IHRGWCBMP	918.43	864.88	13.45	12.94	56.96
IHRGWXCP	920.13	894.83	13.04	3.53	27.70
IHRGWXDP	943.70	897.21	7.29	3.48	46.90
% Saturation					
IHRGWXBP	118.06	114.74	1.38	2.02	3.74
IHRGWCBMP	121.85	114.75	1.86	2.03	7.55
IHRGWXCP	122.08	118.72	1.79	0.35	3.68
IHRGWXDP	125.21	119.03	0.86	0.20	6.23

**Table 1. Statistical summary of measurements and simulations near Ice Harbor Dam for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
IHRGWXBP	88.42	38.95	82.63	81.58
IHRGWCBMP	86.84	0	26.32	25.26
IHRGWXCP	86.32	38.95	77.89	77.89
IHRGWXDP	87.89	0.53	9.47	7.37

**Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near Ice Harbor Dam for the Summer 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_IDSW	17.54	18.15	0.55	0.69	0.77
Concentration (mg/l)					
FMS_IDSW	31.50	30.46	0.37	0.42	1.07
Gas Pressure (mmHg)					
FMS_IDSW	907.53	888.76	4.33	3.22	19.10
% Saturation					
FMS_IDSW	120.4	117.91	0.49	0.59	2.53

**Table 3. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_IDSW	83.16	58.42	100	100

**Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00624P	17.83	18.14	0.48	0.70	0.59
MCN00612P	17.92	18.14	0.35	0.70	0.58
MCN00615P	17.84	18.20	0.51	0.69	0.61
IHR00615B	17.97	18.15	0.48	0.69	0.52
Concentration (mg/l)					
MCN00624P	30.75	30.31	0.39	0.43	0.48
MCN00612P	31.51	30.39	0.64	0.43	1.41
MCN00615P	29.68	29.73	0.49	0.50	0.23
IHR00615B	31.30	30.46	0.32	0.42	0.87
Gas Pressure (mmHg)					
MCN00624P	891.03	884.40	6.02	4.37	8.14
MCN00612P	914.24	886.69	21.39	3.65	35.12
MCN00615P	860.64	868.65	10.19	10.68	13.12
IHR00615B	909.36	888.77	4.36	3.23	20.90
% Saturation					
MCN00624P	118.22	117.34	0.97	0.82	1.08
MCN00612P	121.47	117.64	2.79	0.70	4.96
MCN00615P	114.18	115.25	1.57	1.73	1.74
IHR00615B	120.65	117.91	0.53	0.59	2.77

**Table 5. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00624P	90	98.42	100	100
MCN00612P	91.05	64.21	69.47	69.47
MCN00615P	88.42	100	100	100
IHR00615B	92.63	80.53	100	100

**Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00225P	17.74	18.24	0.50	0.62	0.69
MCN00221P	17.70	18.24	0.50	0.63	0.72
MCN00223P	17.72	18.24	0.59	0.63	0.73
Concentration (mg/l)					
MCN00225P	34.83	30.24	0.71	0.39	4.62
MCN00221P	30.05	30.05	0.39	0.40	0.20
MCN00223P	29.52	29.98	0.41	0.40	0.48
Gas Pressure (mmHg)					
MCN00225P	1005.42	884.03	11.53	5.90	122.02
MCN00221P	868.82	878.46	8.55	6.93	12.37
MCN00223P	854.13	876.34	9.33	7.36	23.24
% Saturation					
MCN00225P	133.39	117.29	1.86	0.95	16.19
MCN00221P	115.27	116.55	1.18	1.16	1.64
MCN00223P	113.32	116.27	1.39	1.25	3.08

**Table 7. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00225P	83.68	0	0	0
MCN00221P	82.63	100	100	100
MCN00223P	80.53	100	98.42	97.89

**Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32613P	16.90	16.93	0.28	0.24	0.08
Concentration (mg/l)					
MCN32613P	31.31	31.31	0.46	0.45	0.05
Gas Pressure (mmHg)					
MCN32613P	891.04	891.98	12.73	12.67	1.85
% Saturation					
MCN32613P	118.22	118.35	2.06	2.06	0.25

**Table 9. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32613P	100	100	100	100

**Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32353P	17.05	16.93	0.28	0.24	0.20
MCN32352P	17.12	16.97	0.28	0.23	0.20
MCN32351P	17.39	18.13	0.36	0.51	0.84
Concentration (mg/l)					
MCN32353P	31.12	31.32	0.46	0.45	0.21
MCN32352P	31.18	31.29	0.41	0.44	0.16
MCN32351P	30.68	30.19	0.37	0.34	0.56
Gas Pressure (mmHg)					
MCN32353P	888.02	891.95	11.70	12.72	4.69
MCN32352P	890.84	892.13	11.12	12.70	3.77
MCN32351P	881.29	880.62	8.67	7.79	5.69



% Saturation					
MCN32353P	117.82	118.34	1.93	2.08	0.62
MCN32352P	118.20	118.37	1.87	2.07	0.50
MCN32351P	116.92	116.83	1.40	1.31	0.75

**Table 11. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32353P	100	100	100	100
MCN32352P	100	100	100	100
MCN32351P	74.74	96.84	100	100

**Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN31423P	17.23	17.28	0.28	0.29	0.13
MCN31422P	17.91	18.53	0.40	0.70	0.75
MCN31421P	17.49	17.54	0.36	0.33	0.21
MCN31424P	17.11	17.06	0.26	0.31	0.11
Concentration (mg/l)					
MCN31423P	31.01	31.04	0.47	0.41	0.19
MCN31422P	29.86	30.02	0.95	0.86	1.42
MCN31421P	30.30	30.82	0.66	0.35	0.77
MCN31424P	31.20	31.26	0.49	0.48	0.15
Gas Pressure (mmHg)					
MCN31423P	888.43	890.29	13.33	13.11	5.37
MCN31422P	866.85	882.96	24.06	34.85	47.05
MCN31421P	872.45	888.69	16.37	11.98	22.00
MCN31424P	891.49	892.74	14.31	15.43	4.22
% Saturation					
MCN31423P	117.87	118.12	2.07	2.08	0.72
MCN31422P	115.01	117.15	3.44	4.73	6.24
MCN31421P	115.75	117.91	2.39	1.91	2.92
MCN31424P	118.27	118.45	2.24	2.39	0.56

**Table 13. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN31423P	100	100	100	100
MCN31422P	80.00	52.63	54.74	54.21
MCN31421P	100	82.63	91.05	91.05
MCN31424P	100	100	100	100

**Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN30661P	17.52	18.32	0.27	0.60	0.88
MCN30663P	17.43	17.61	0.23	0.31	0.23
Concentration (mg/l)					
MCN30661P	30.19	30.13	0.42	0.92	1.06
MCN30663P	30.74	30.96	0.44	0.33	0.35
Gas Pressure (mmHg)					
MCN30661P	870.24	882.46	10.21	35.00	37.53
MCN30663P	883.98	893.82	11.00	11.32	13.28
% Saturation					
MCN30661P	115.50	117.11	1.75	4.55	4.97
MCN30663P	117.32	118.62	1.87	1.75	1.76

**Table 15. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN30661P	75.76	69.09	52.12	50.30
MCN30663P	100	100	100	100

**Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_MCQW	18.85	17.47	0.51	0.27	1.48
FMS_MCQO	17.81	17.89	0.70	0.37	0.57

Concentration (mg/l)					
FMS_MCQW	30.37	31.31	0.26	0.57	1.10
FMS_MCQO	30.36	30.55	0.22	0.62	0.56
Gas Pressure (mmHg)					
FMS_MCQW	897.70	901.36	7.81	19.42	22.74
FMS_MCQO	879.61	887.33	14.10	23.42	19.85
% Saturation					
FMS_MCQW	118.68	119.55	1.41	2.33	3.21
FMS_MCQO	116.29	117.69	1.69	2.78	2.92

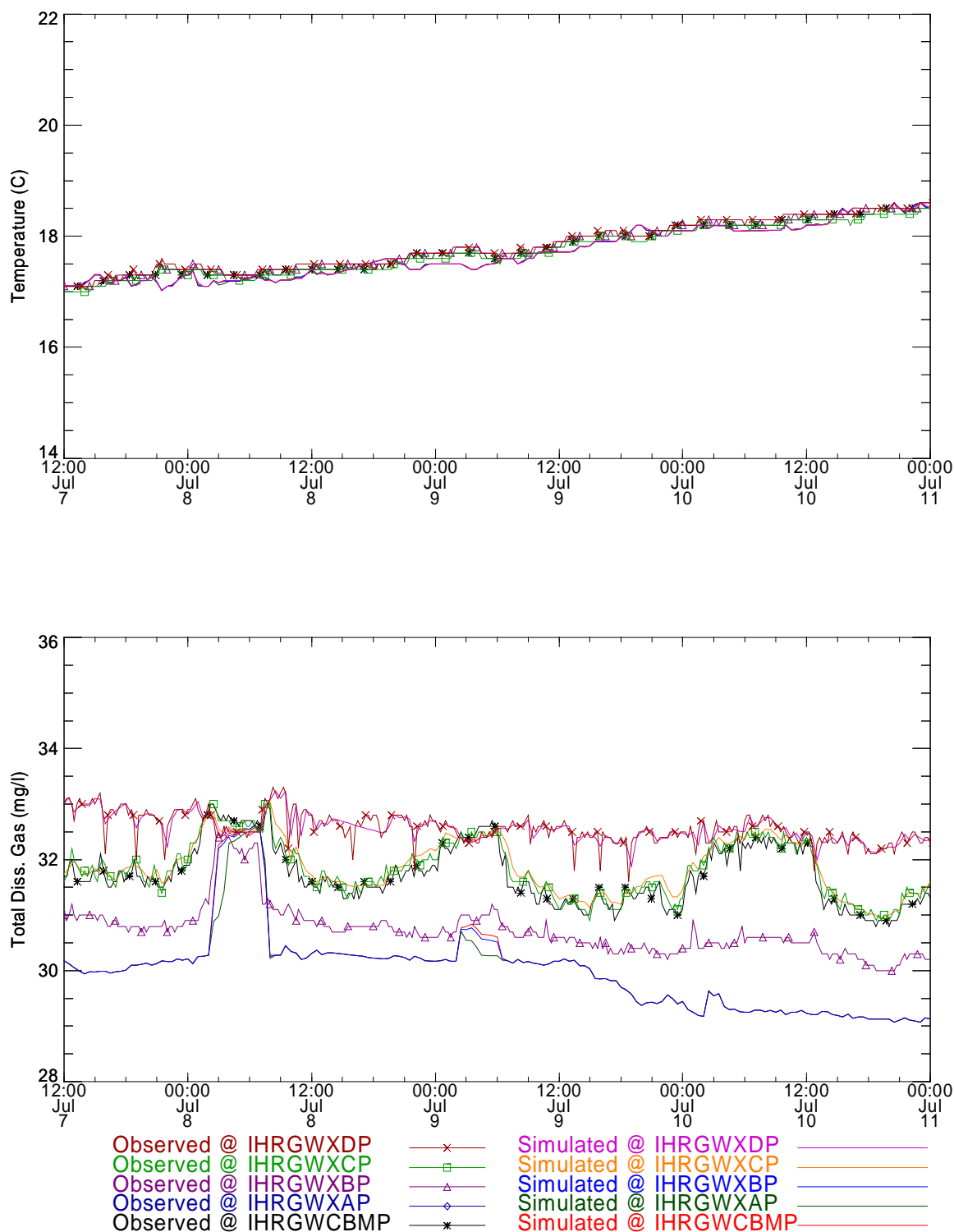
**Table 17. Statistical summary of measurements and simulations for the Summer 1996 pool study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_MCQW	33.33	51.67	92.50	92.50
FMS_MCQO	94.17	97.50	97.50	95.00

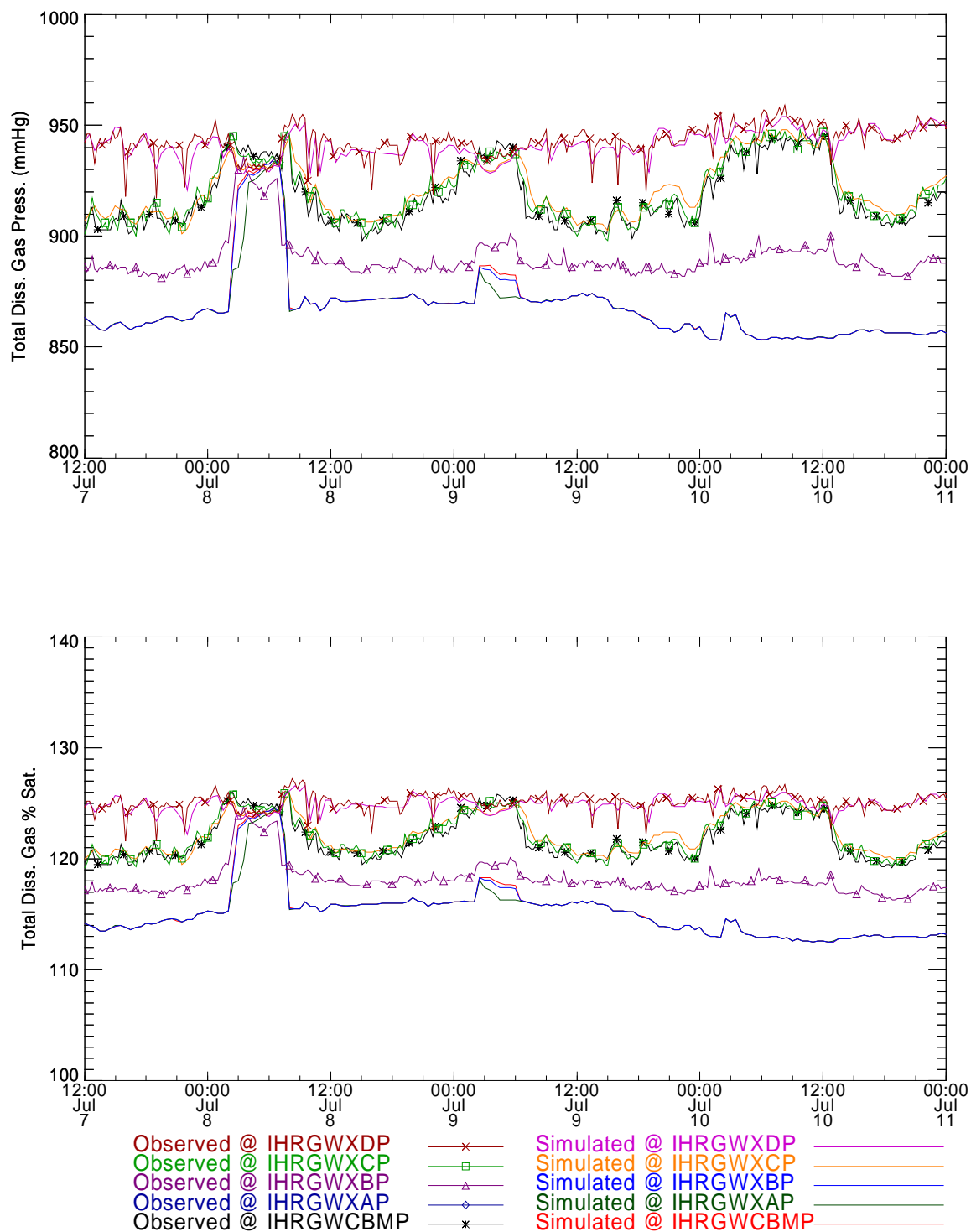
**Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. FMS-BC**

#### **Boundary Conditions using Temporary Monitored Field Data**

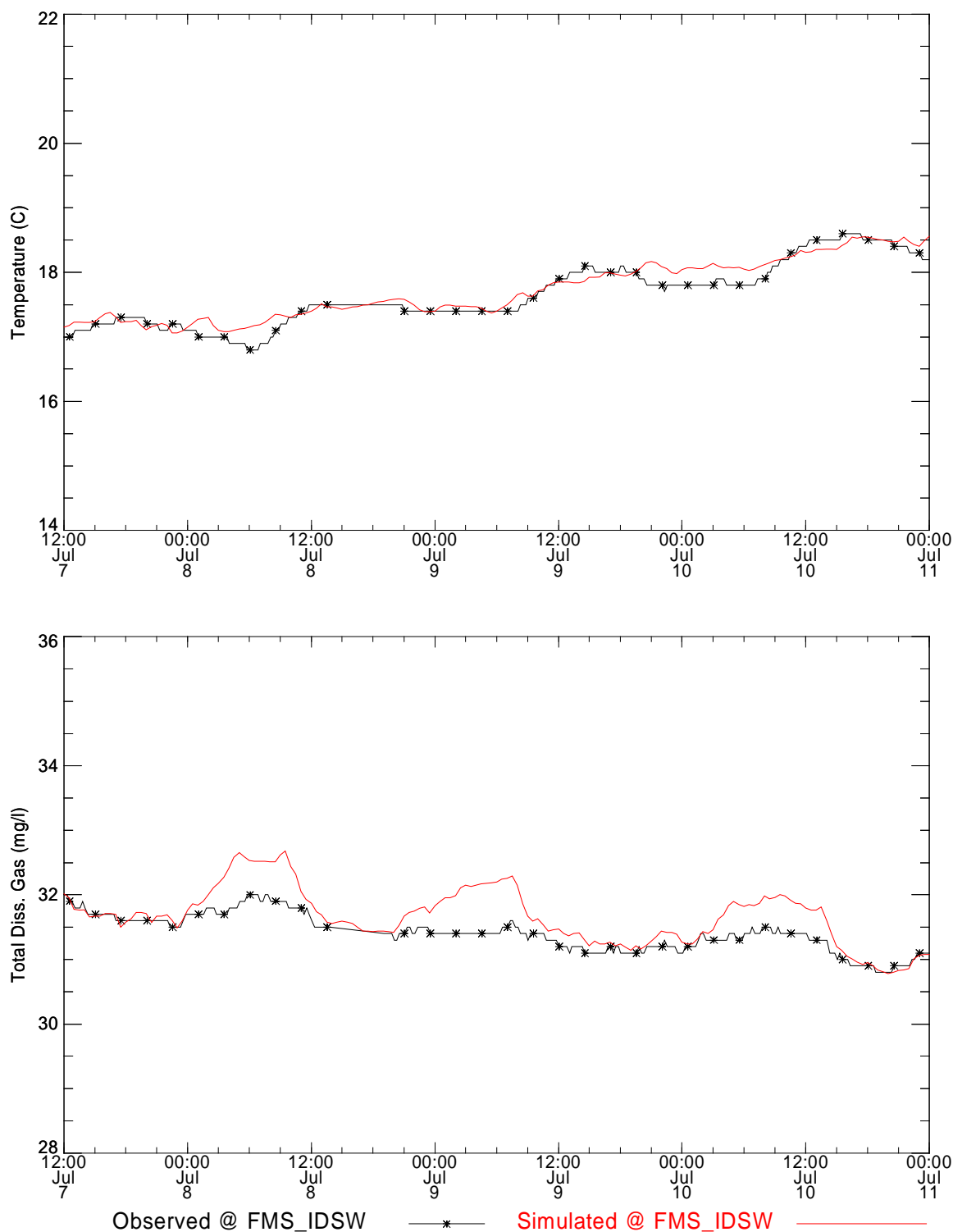
Comparisons between the measurements and simulations using an upstream boundary condition developed from the furthest upstream temporary gas monitor and the gas monitor located at the draft tube are shown in the Figures below. This case is denoted as TM-BC in the figure captions.



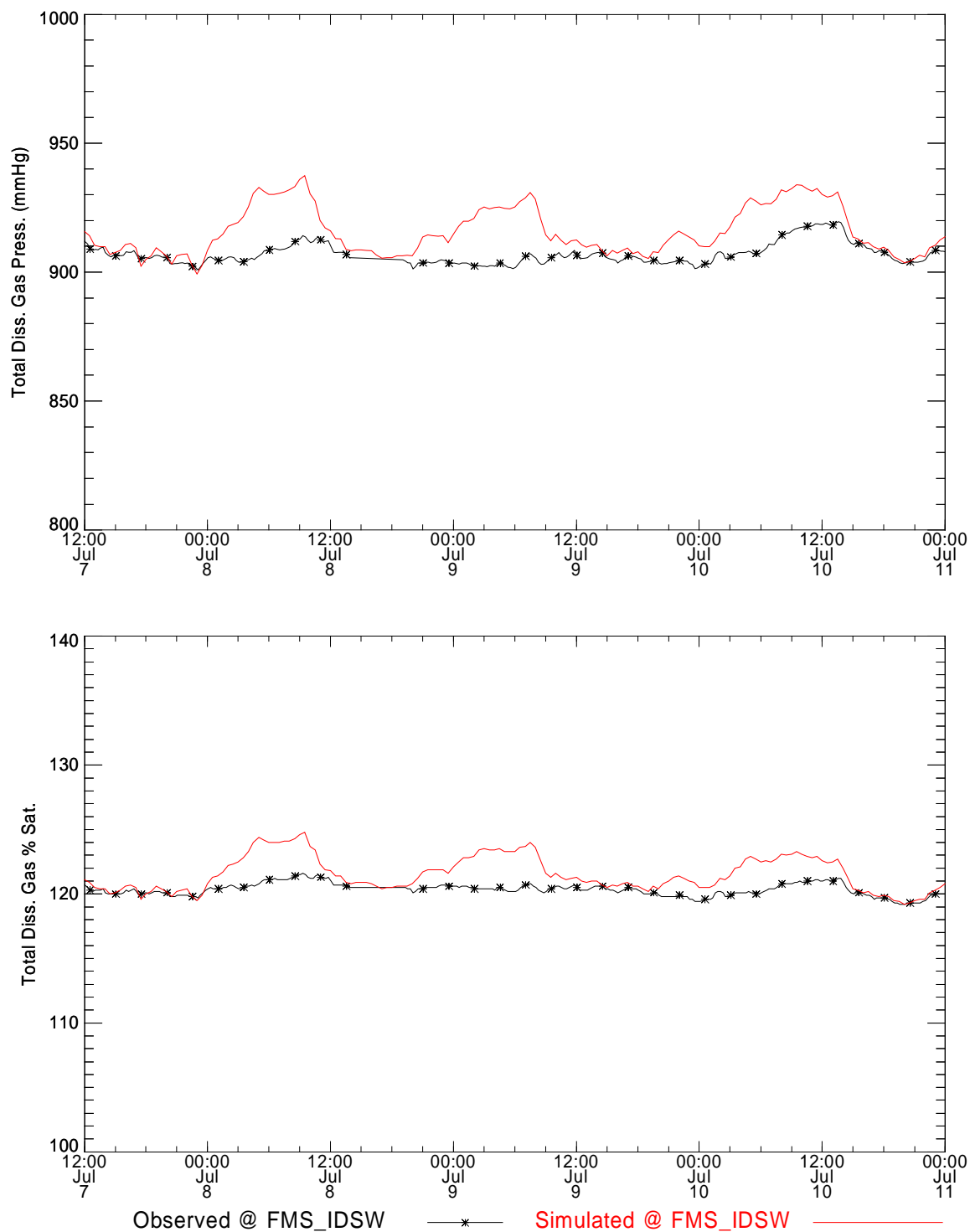
**Figure 67. Temperature and total dissolved gas time series comparisons near Ice Harbor Dam for the Summer 1996 pool study (TM-BC).**



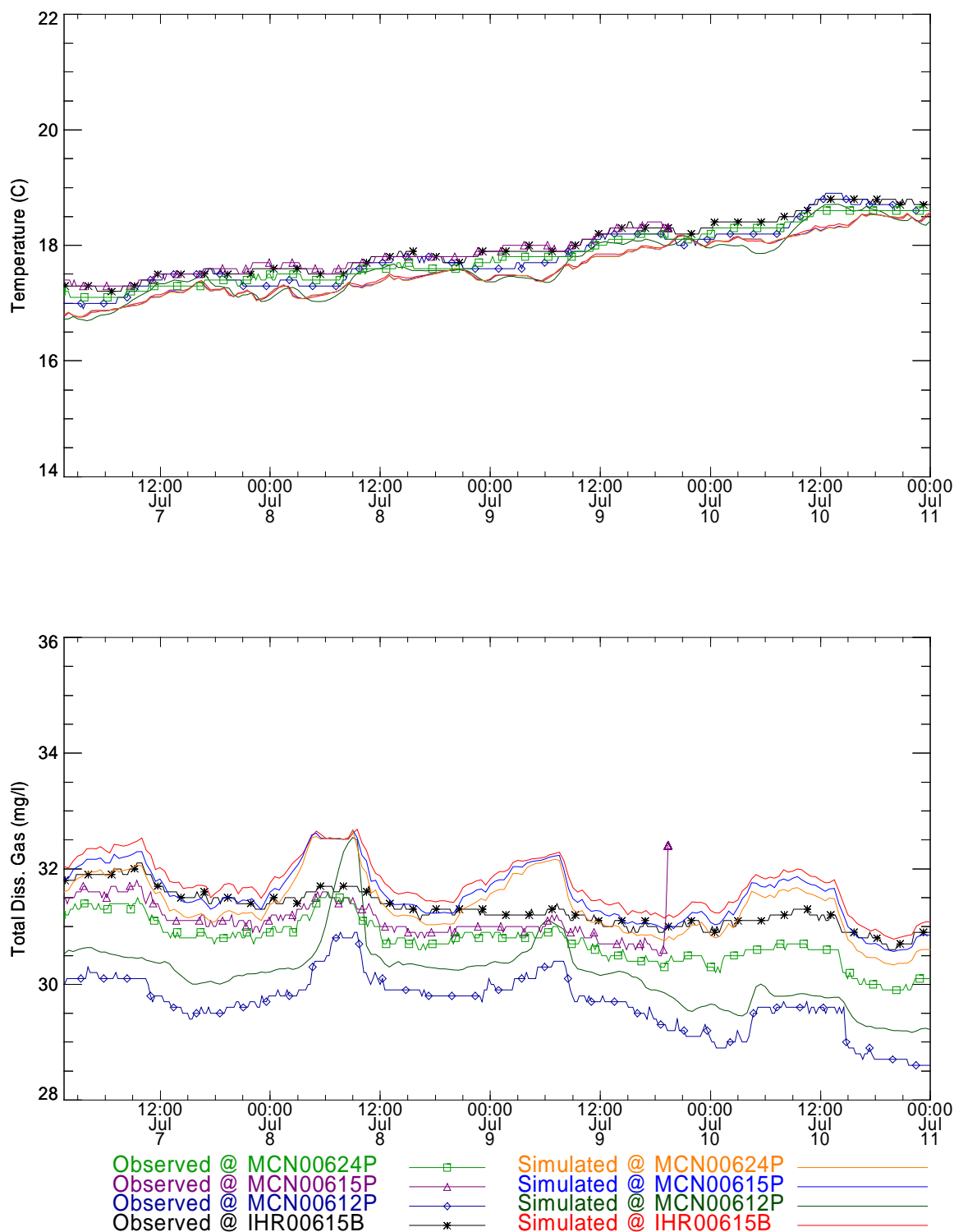
**Figure 68. Total dissolved gas time series comparisons near Ice Harbor Dam for the Summer 1996 pool study (TM-BC).**



**Figure 69. Temperature and total dissolved gas time series comparisons near the Ice Harbor Fixed Monitor for the Summer 1996 pool study (TM-BC).**

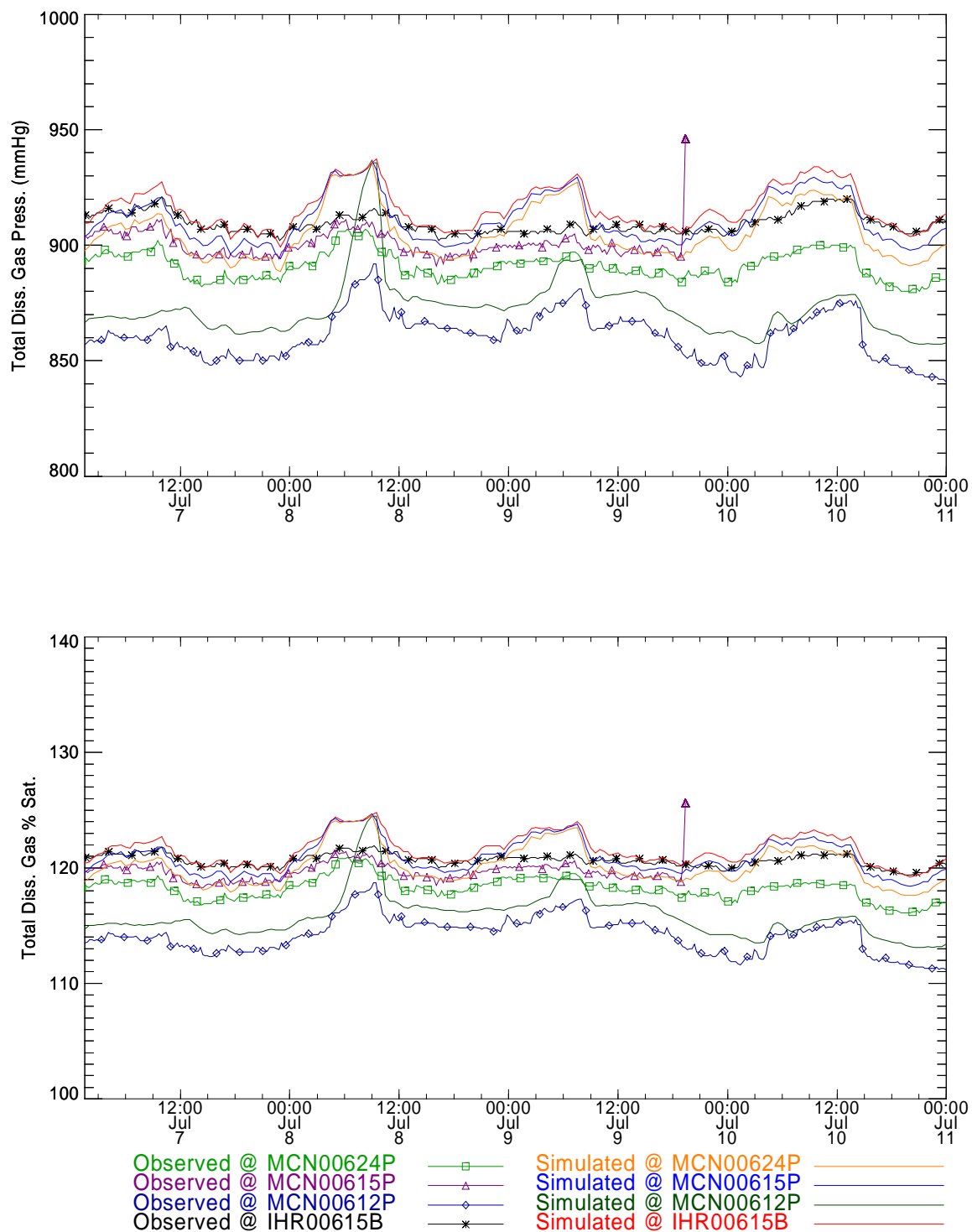


**Figure 70. Total dissolved gas time series comparisons near the Ice Harbor Fixed Monitor for the Summer 1996 pool study (TM-BC).**

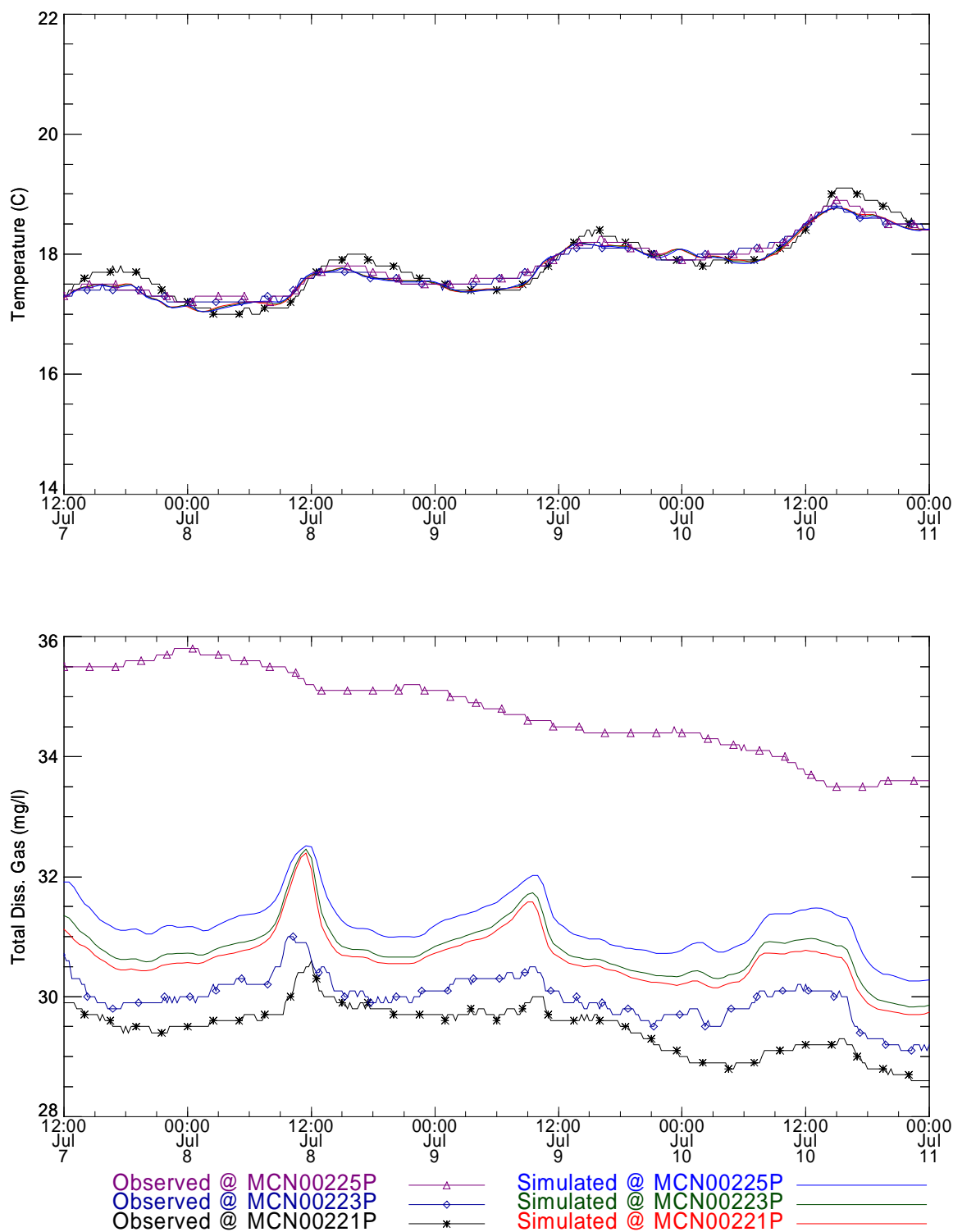


**Figure 71. Temperature and total dissolved gas time series comparisons near Snake River Mile 6.1 for the Summer 1996 pool study.**

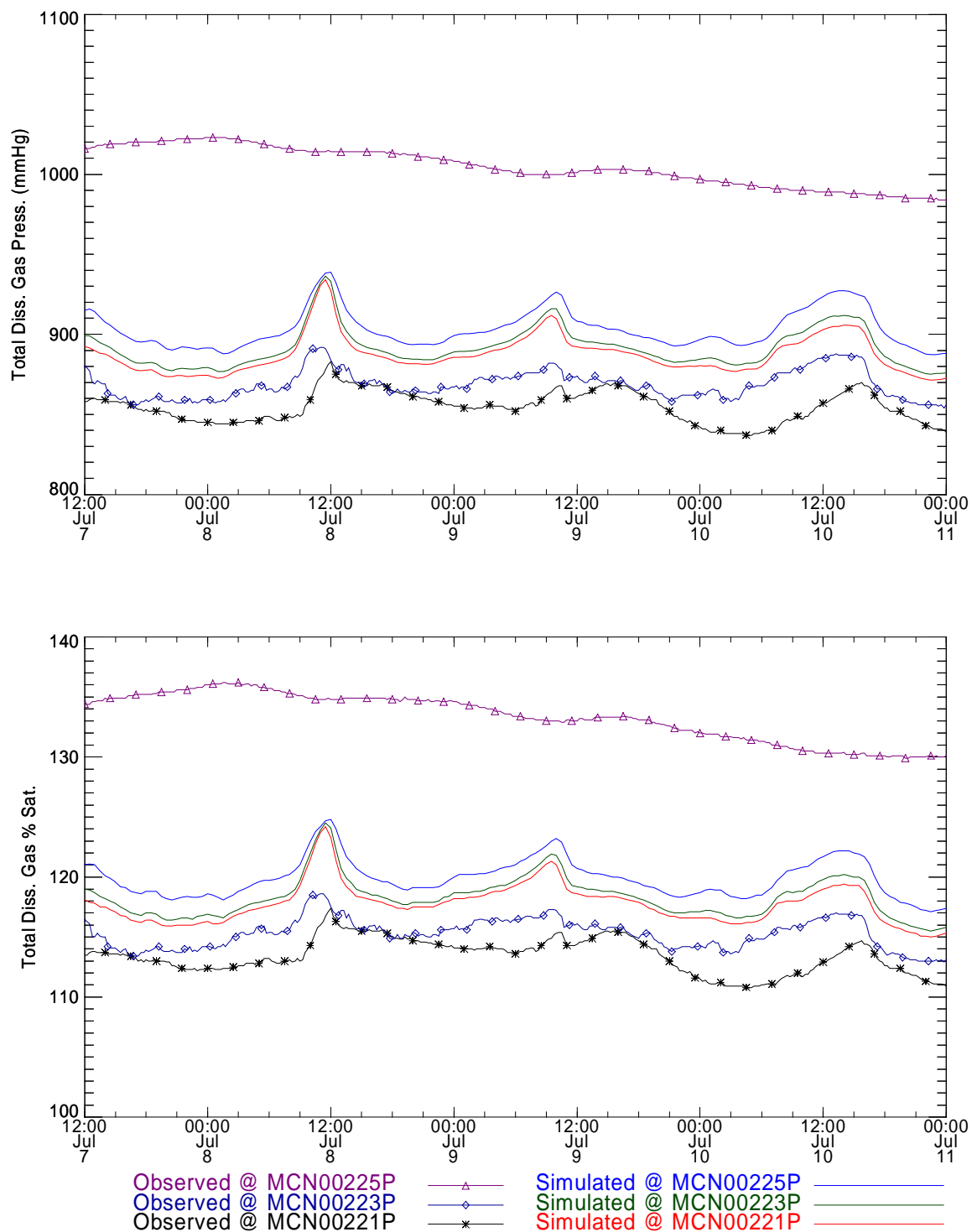




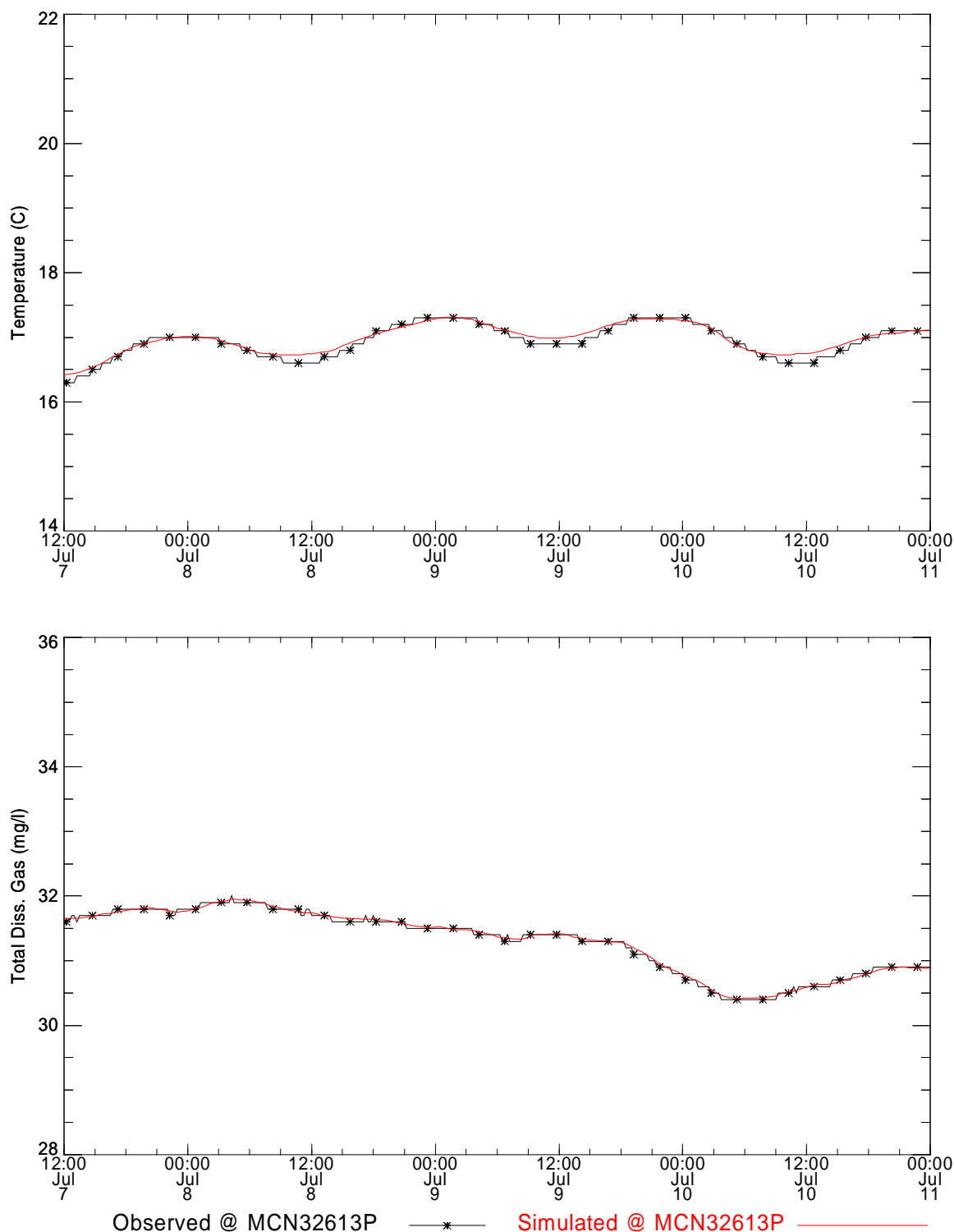
**Figure 72. Total dissolved gas time series comparisons near Snake River Mile 6.1 for the Summer 1996 pool study (TM-BC).**



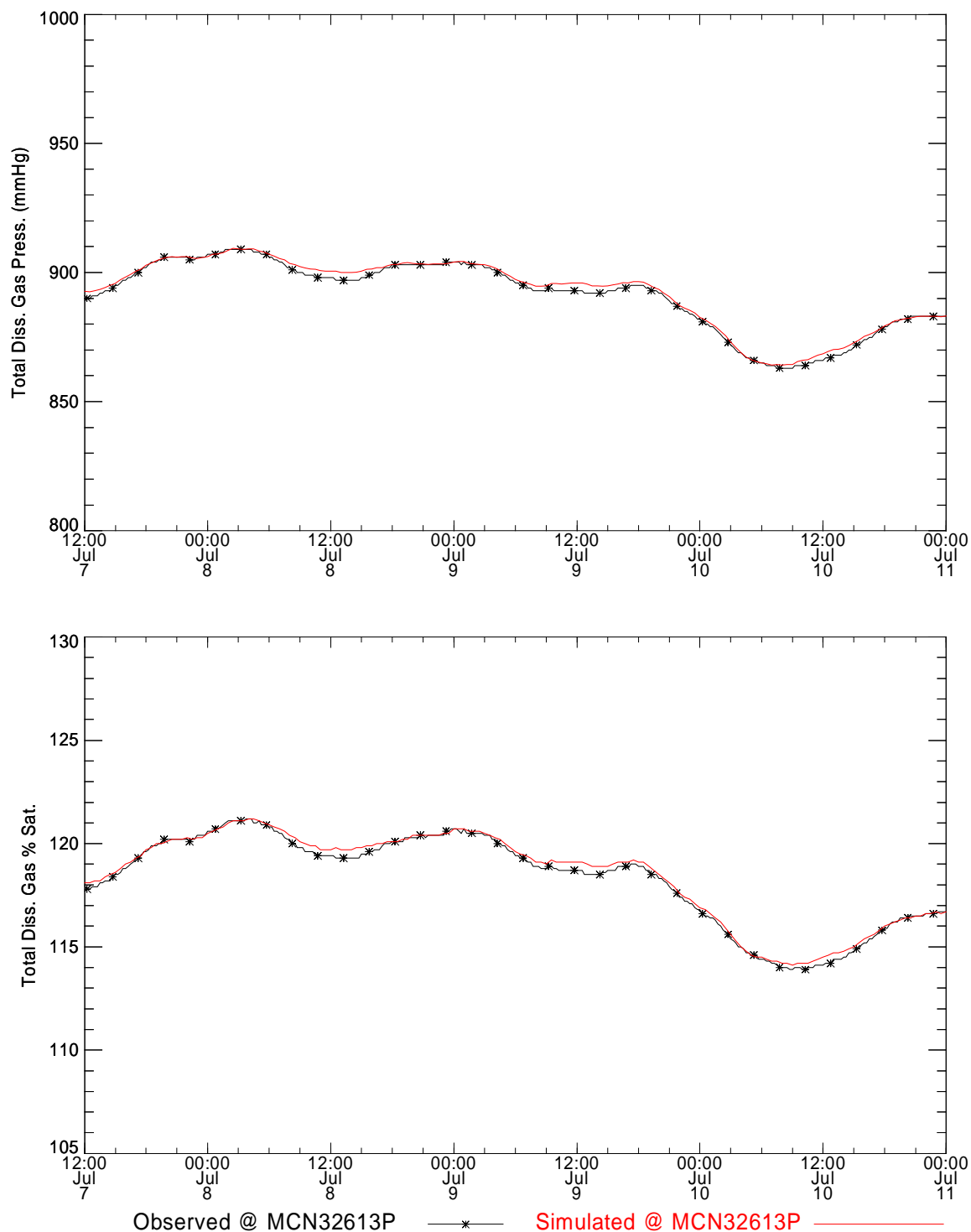
**Figure 73. Temperature and total dissolved gas time series comparisons near Snake River Mile 2.2 for the Summer 1996 pool study (TM-BC).**



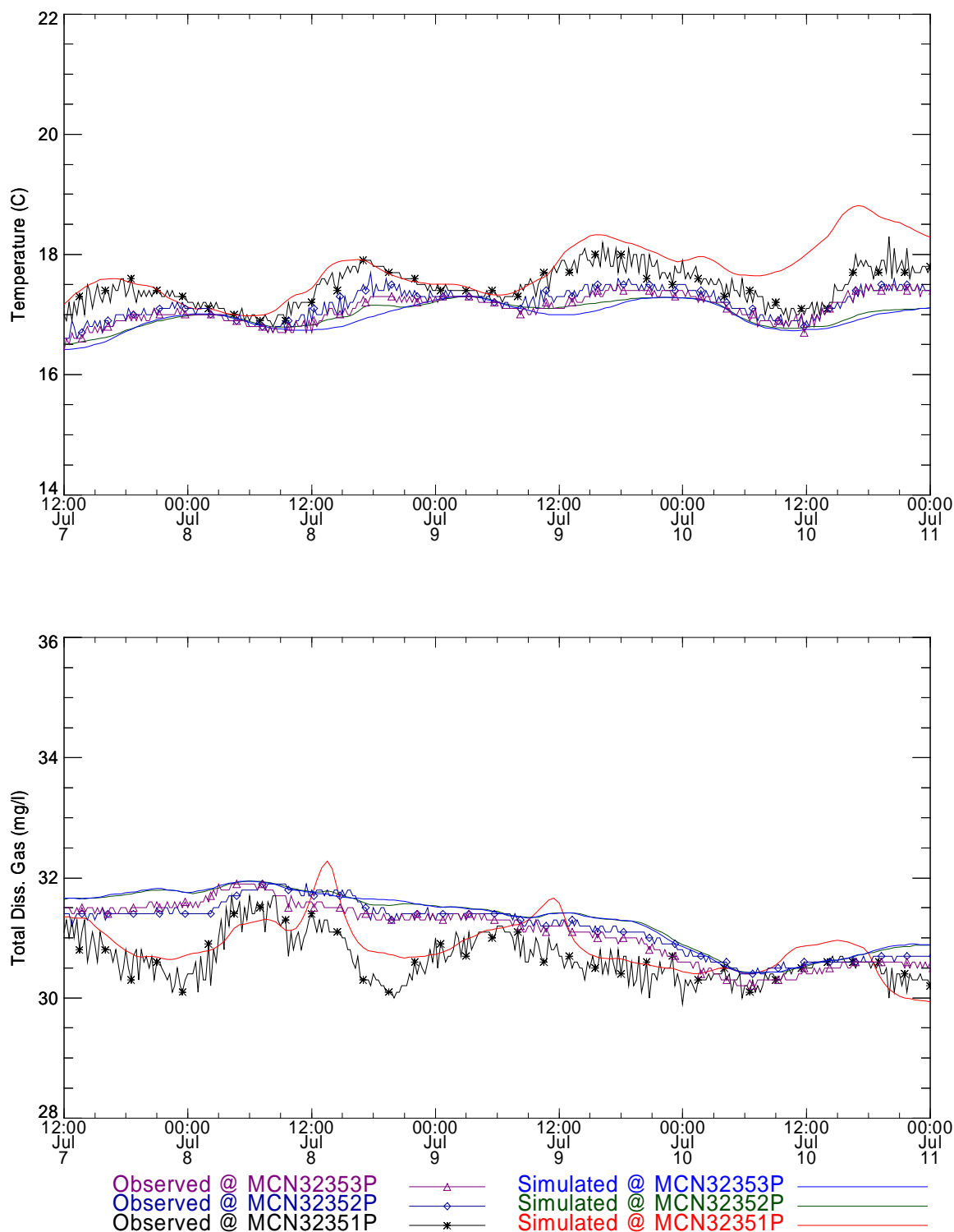
**Figure 74. Total dissolved gas time series comparisons near Snake River Mile 2.2 for the Summer 1996 pool study (TM-BC).**



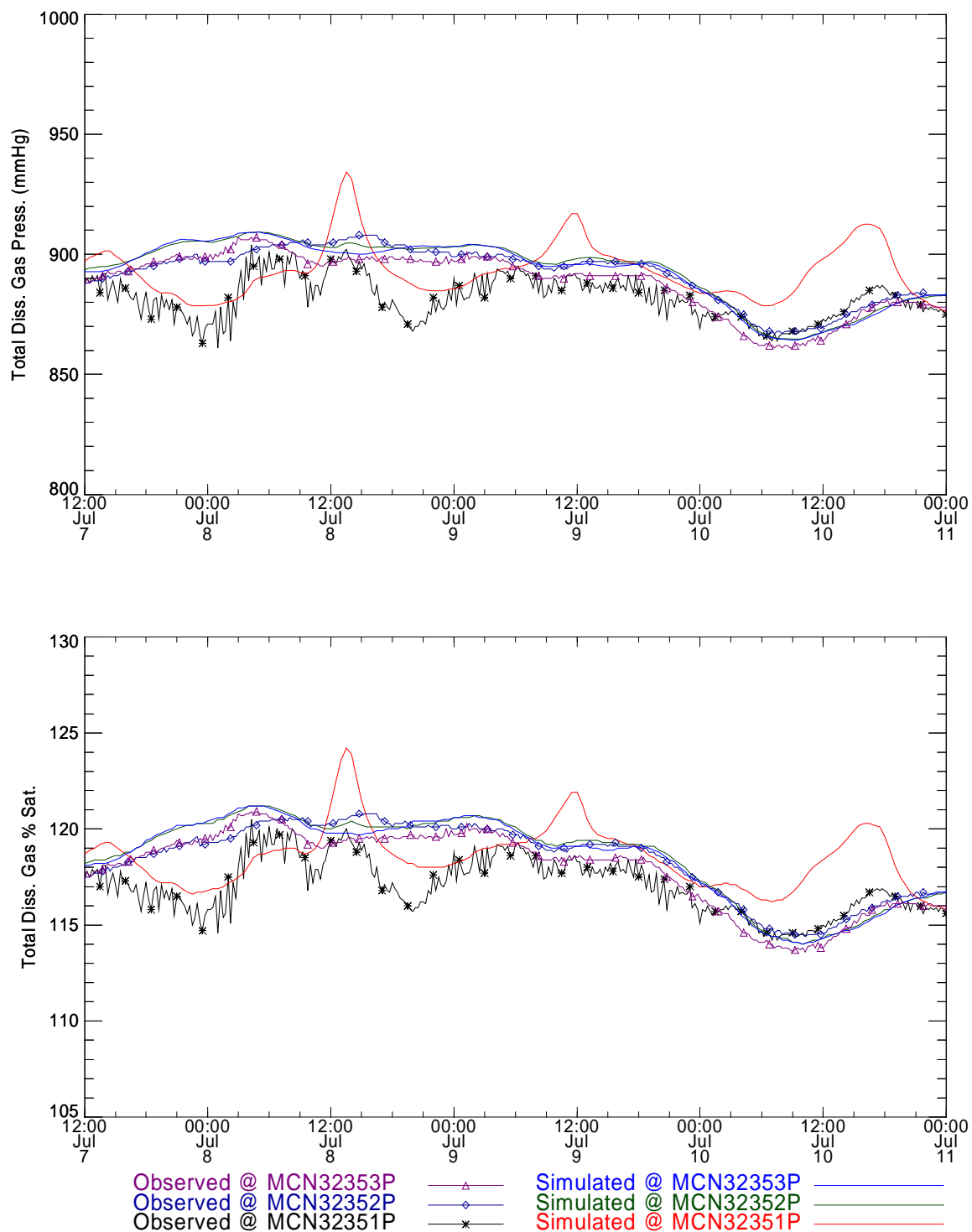
**Figure 75. Temperature and total dissolved gas concentration at Columbia River Mile 326.1. Note that this monitor supplied the model boundary conditions at Clover Island (TM-BC).**



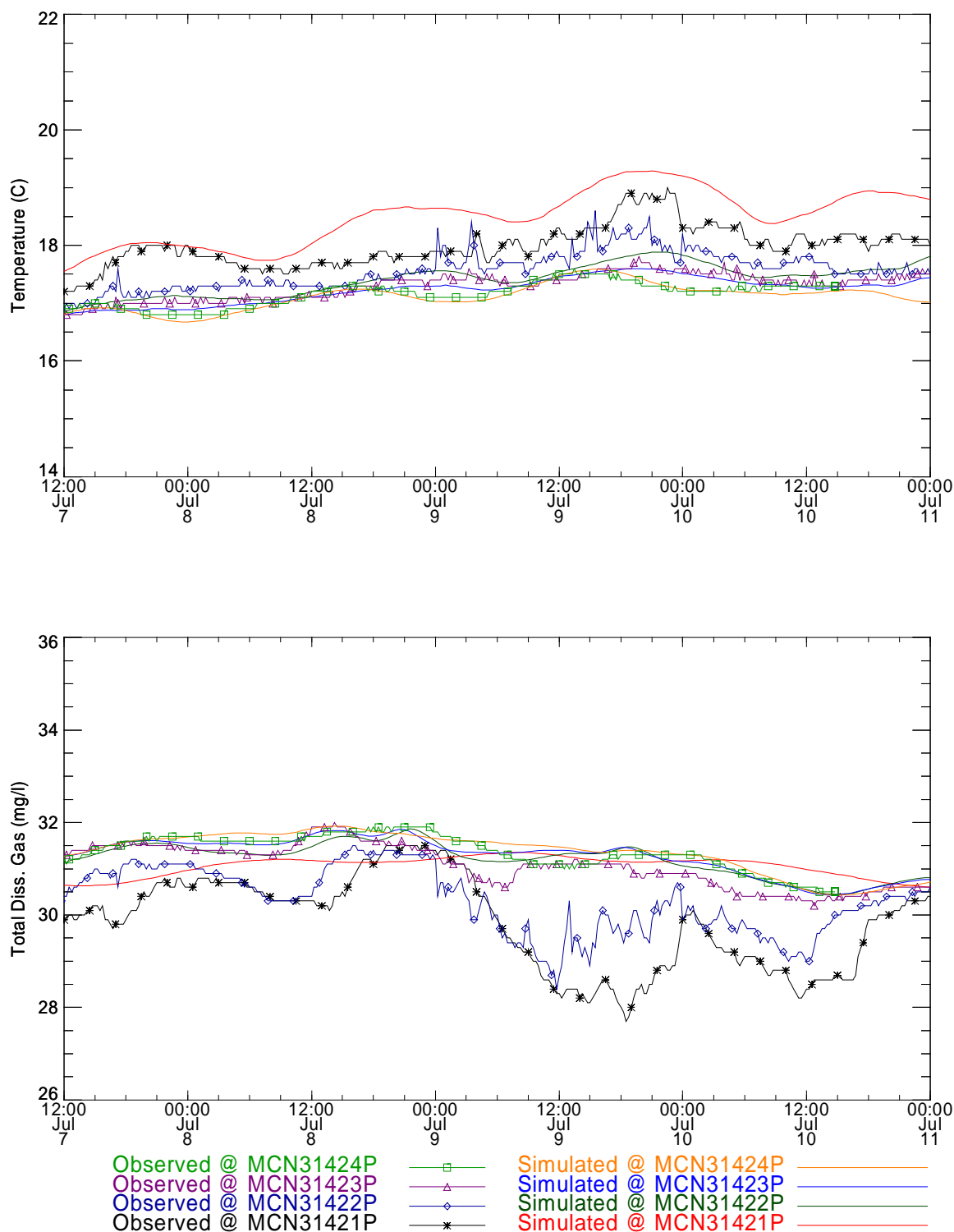
**Figure 76. Total dissolved gas at Columbia River Mile 326.1. Note that this monitor supplied the model boundary conditions at Clover Island (TM-BC).**



**Figure 77. Temperature and total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Summer 1996 pool study (TM-BC).**

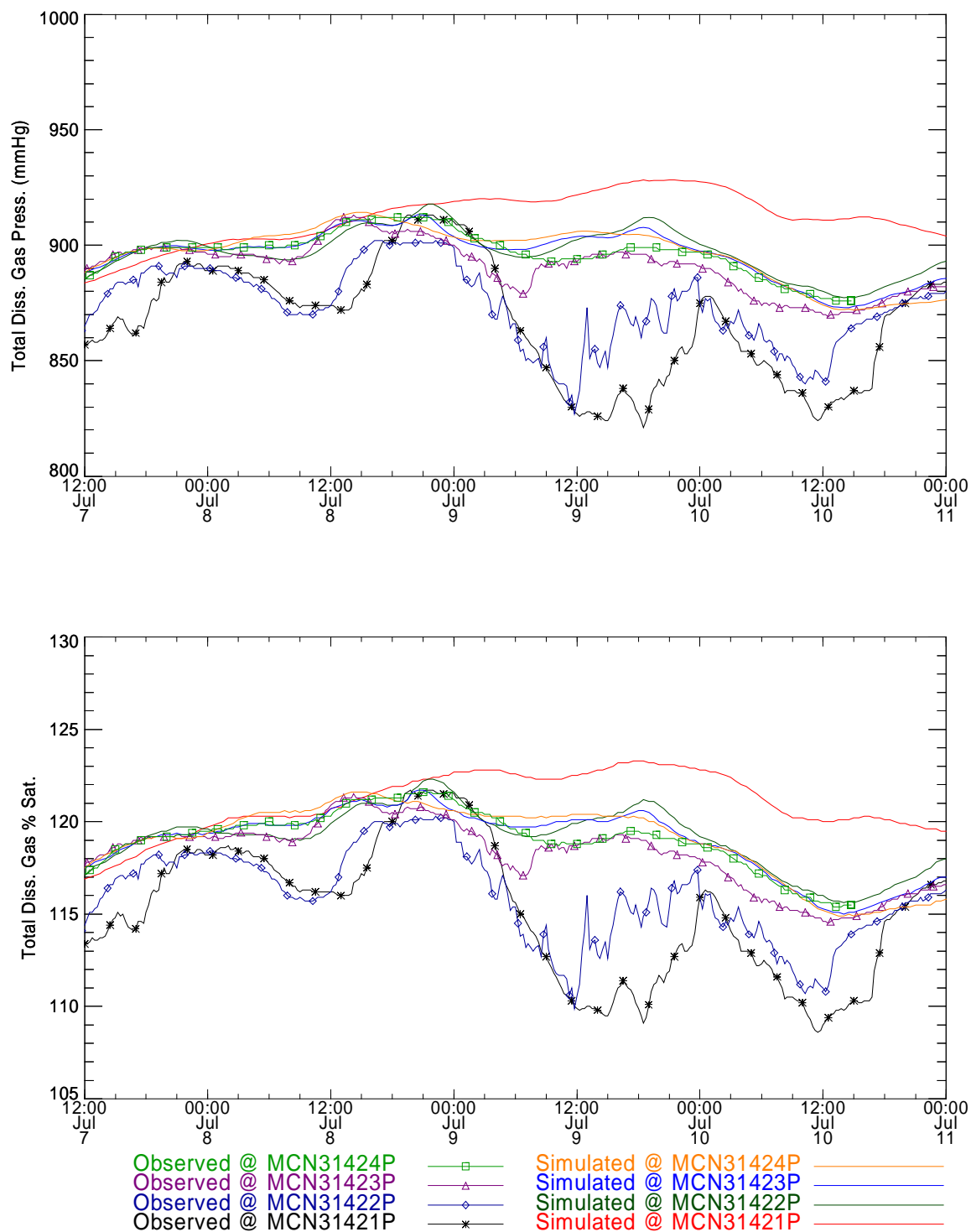


**Figure 78. Total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Summer 1996 pool study (TM-BC).**

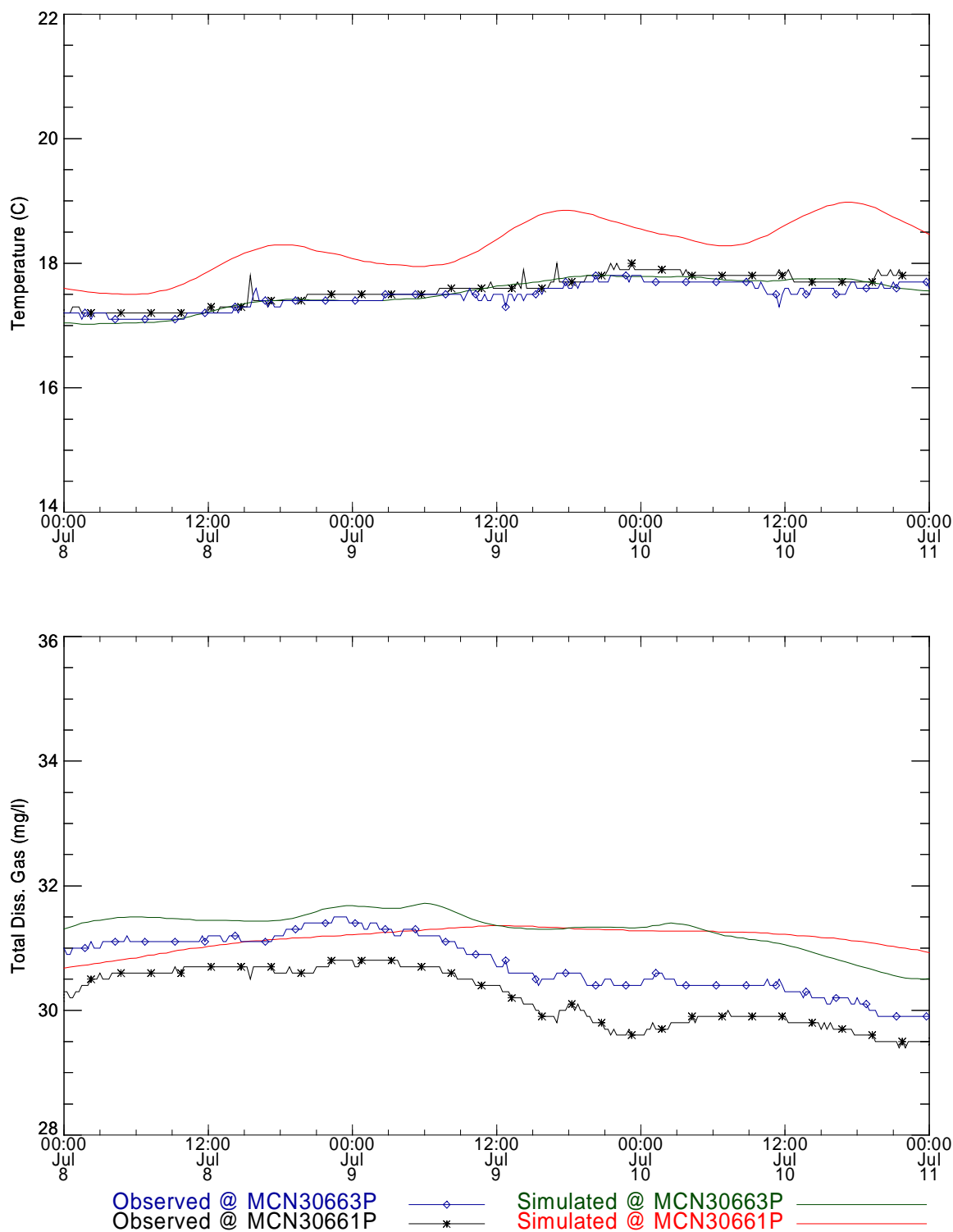


**Figure 79. Temperature and total dissolved gas time series comparisons near Columbia River Mile 314 for the Summer 1996 pool study (TM-BC).**

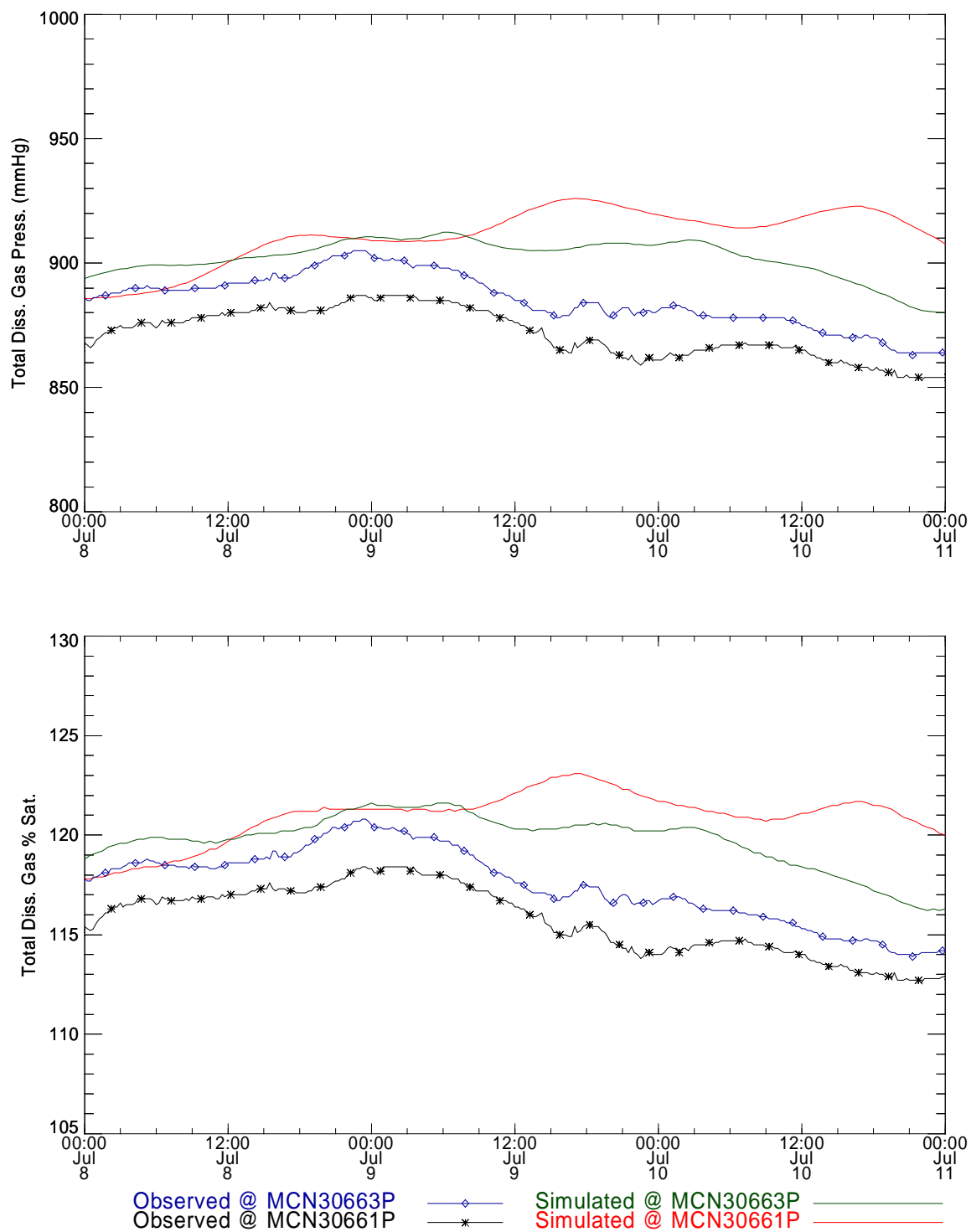




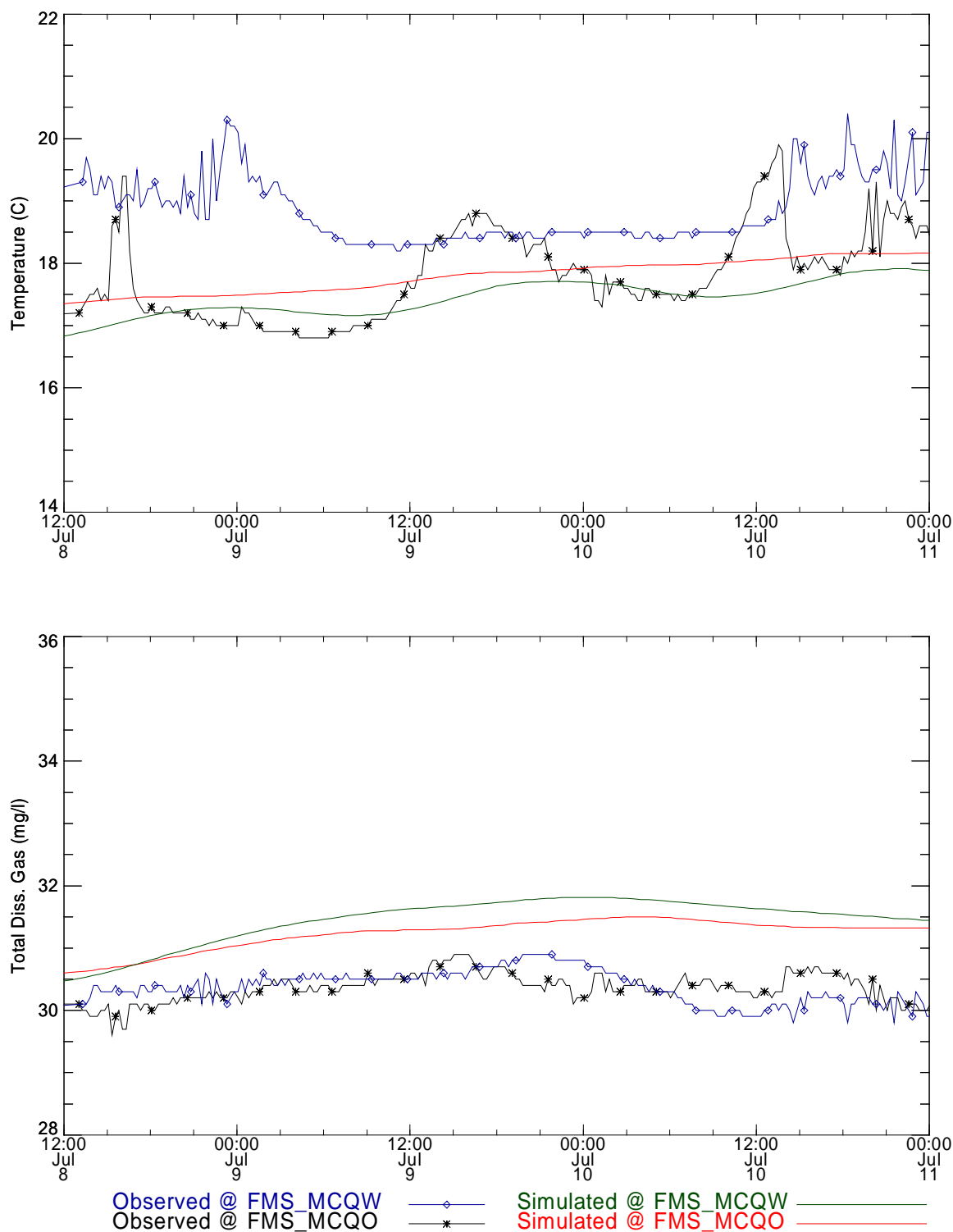
**Figure 80. Total dissolved gas time series comparisons near Columbia River Mile 314 for the Summer 1996 pool study (TM-BC).**



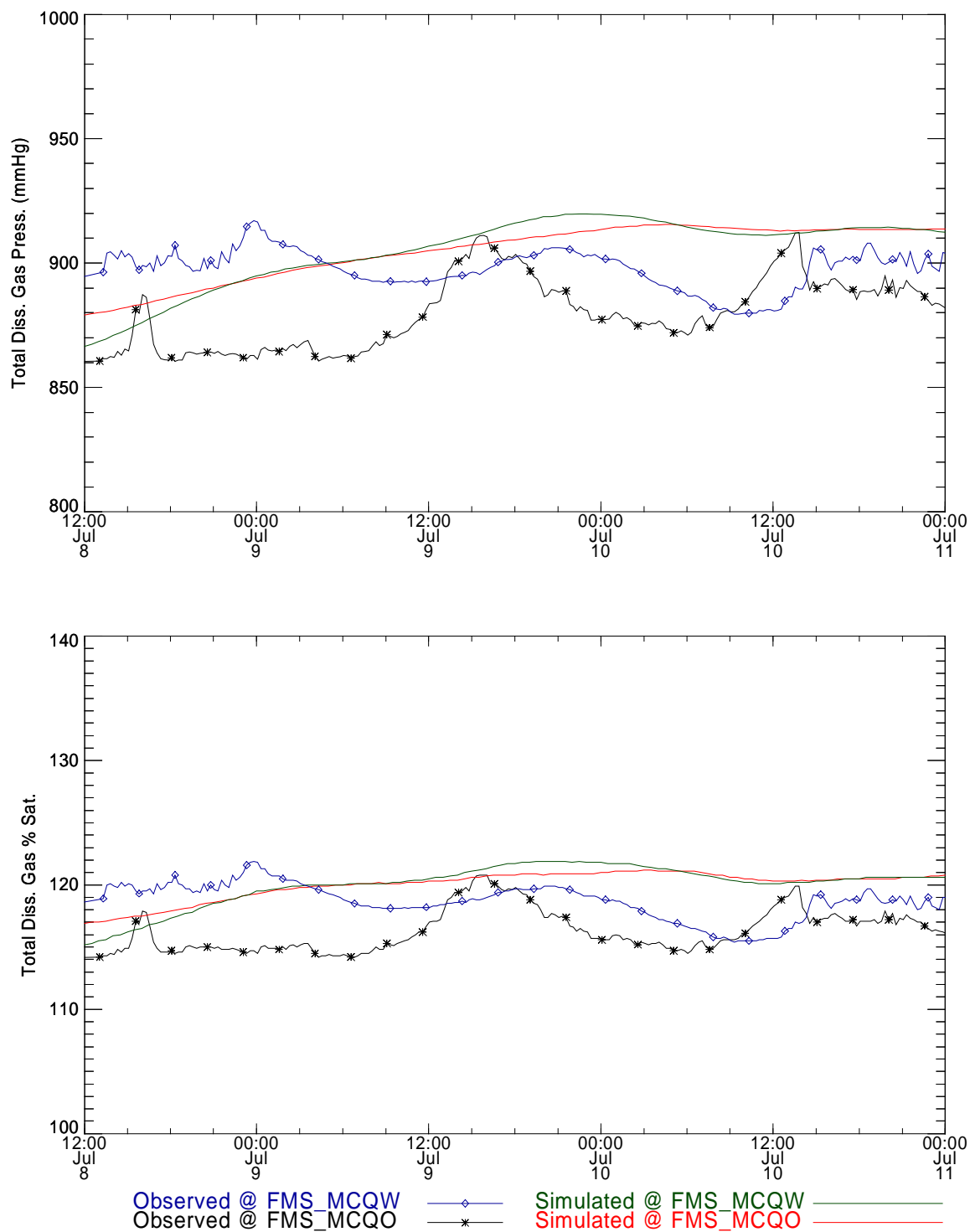
**Figure 81. Temperature and total dissolved gas time series comparisons near Columbia River Mile 306 for the Summer 1996 pool study (TM-BC).**



**Figure 82. Total dissolved gas time series comparisons near Columbia River Mile 306 for the Summer 1996 pool study (TM-BC).**



**Figure 83. Temperature and total dissolved gas time series comparisons at the McNary Fixed Monitor for the Summer 1996 pool study (TM-BC).**



**Figure 84. Total dissolved gas time series comparisons at the McNary Fixed Monitor for the Summer 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
IHRGWXBP	17.56	17.45	0.62	0.62	0.16
IHRGWCBMP	17.52	17.45	0.61	0.62	0.14
IHRGWXCP	17.48	17.45	0.62	0.62	0.13
IHRGWXDP	17.58	17.45	0.63	0.62	0.18
Concentration (mg/l)					
IHRGWXBP	30.87	29.95	0.45	0.66	1.03
IHRGWCBMP	31.88	29.95	0.53	0.67	2.03
IHRGWXCP	31.98	32.00	0.52	0.50	0.14
IHRGWXDP	32.79	32.80	0.54	0.52	0.16
Gas Pressure (mmHg)					
IHRGWXBP	889.83	862.30	8.21	15.94	30.30
IHRGWCBMP	917.82	862.42	12.49	16.18	58.20
IHRGWXCP	919.90	920.44	12.58	12.47	4.05
IHRGWXDP	944.51	943.12	8.59	7.62	5.00
% Saturation					
IHRGWXBP	117.79	114.15	1.32	2.53	4.00
IHRGWCBMP	121.50	114.16	1.81	2.56	7.71
IHRGWXCP	121.77	121.84	1.80	1.81	0.54
IHRGWXDP	125.03	124.84	1.09	0.90	0.67

**Table 19. Statistical summary of measurements and simulations near Ice Harbor Dam for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
IHRGWXBP	100	55.12	73.14	74.20
IHRGWCBMP	100	4.59	13.78	13.78
IHRGWXCP	100	100	100	100
IHRGWXDP	100	100	100	100

**Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near Ice Harbor Dam for the Summer 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_IDSW	17.42	17.54	0.69	0.60	0.21
Concentration (mg/l)					
FMS_IDSW	31.61	31.77	0.48	0.46	0.33
Gas Pressure (mmHg)					
FMS_IDSW	908.40	915.44	4.45	9.15	10.65
% Saturation					
FMS_IDSW	120.32	121.26	0.50	1.38	1.43

**Table 21. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_IDSW	100	100	100	100

**Table 22. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00225P	17.57	17.55	0.64	0.68	0.29
MCN00221P	17.55	17.55	0.64	0.68	0.28
MCN00223P	17.57	17.55	0.69	0.68	0.28
Concentration (mg/l)					
MCN00225P	34.68	31.17	0.78	0.48	3.56
MCN00221P	29.99	30.73	0.40	0.48	0.76
MCN00223P	29.43	30.57	0.40	0.47	1.18
Gas Pressure (mmHg)					
MCN00225P	997.99	898.76	17.98	12.42	100.98
MCN00221P	864.59	886.17	11.60	13.07	22.41
MCN00223P	849.10	881.73	11.59	12.95	33.76
% Saturation					
MCN00225P	132.11	118.97	2.83	1.87	13.38
MCN00221P	114.45	117.31	1.80	2.00	2.97
MCN00223P	112.40	116.72	1.86	2.01	4.47

**Table 23. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00225P	98.23	0.00	0.35	0.35
MCN00221P	98.23	95.41	96.82	96.82
MCN00223P	98.23	32.51	71.02	71.38

**Table 24. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00624P	17.66	17.47	0.63	0.62	0.25
MCN00612P	17.73	17.47	0.48	0.62	0.37
MCN00615P	17.68	17.52	0.64	0.66	0.24
IHR00615B	17.80	17.48	0.63	0.62	0.37
Concentration (mg/l)					
MCN00624P	30.79	31.35	0.40	0.50	0.63
MCN00612P	31.54	31.56	0.57	0.47	0.79
MCN00615P	29.58	30.07	0.48	0.55	0.54
IHR00615B	31.43	31.76	0.42	0.45	0.46
Gas Pressure (mmHg)					
MCN00624P	889.23	902.42	7.70	13.11	15.02
MCN00612P	911.79	908.45	20.92	11.68	19.41
MCN00615P	855.22	867.08	12.61	14.09	13.28
IHR00615B	910.08	914.05	4.51	10.05	9.03
% Saturation					
MCN00624P	117.71	119.46	1.33	2.04	1.99
MCN00612P	120.87	120.25	2.96	1.83	2.86
MCN00615P	113.21	114.78	2.05	2.26	1.76
IHR00615B	120.47	121.00	0.63	1.59	1.21

**Table 25. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00624P	99.65	90.11	99.65	99.65
MCN00612P	99.65	74.91	90.81	85.51
MCN00615P	99.29	97.88	98.59	98.59
IHR00615B	99.65	99.65	100	100

**Table 26. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**



Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32613P	16.76	16.79	0.34	0.32	0.09
Concentration (mg/l)					
MCN32613P	31.07	31.08	0.56	0.55	0.09
Gas Pressure (mmHg)					
MCN32613P	881.77	883.02	18.63	18.51	3.38
% Saturation					
MCN32613P	116.73	116.90	2.94	2.91	0.44

**Table 27. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32613P	100	100	100	100

**Table 28. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32353P	16.92	16.79	0.34	0.32	0.20
MCN32352P	17.01	16.85	0.32	0.30	0.22
MCN32351P	17.25	17.53	0.39	0.65	0.54
Concentration (mg/l)					
MCN32353P	30.91	31.08	0.52	0.55	0.22
MCN32352P	31.06	31.09	0.39	0.53	0.23
MCN32351P	30.57	30.78	0.42	0.43	0.40
Gas Pressure (mmHg)					
MCN32353P	879.71	883.06	16.73	18.44	5.65
MCN32352P	885.47	884.23	12.66	17.78	6.82
MCN32351P	875.84	887.24	12.88	13.58	14.86
% Saturation					
MCN32353P	116.46	116.90	2.67	2.90	0.75
MCN32352P	117.22	117.05	2.15	2.81	0.90
MCN32351P	115.94	117.45	2.08	2.05	1.96

**Table 29. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32353P	100	100	100	100
MCN32352P	100	100	100	100
MCN32351P	90.81	98.94	98.23	98.23

**Table 30. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN31423P	17.10	17.08	0.34	0.34	0.20
MCN31422P	17.75	18.28	0.47	0.50	0.64
MCN31421P	17.33	17.28	0.41	0.40	0.32
MCN31424P	16.99	16.95	0.33	0.34	0.16
Concentration (mg/l)					
MCN31423P	30.81	31.03	0.50	0.46	0.27
MCN31422P	29.89	30.88	0.85	0.30	1.37
MCN31421P	30.31	30.98	0.57	0.41	0.86
MCN31424P	30.93	31.07	0.57	0.53	0.22
Gas Pressure (mmHg)					
MCN31423P	880.35	886.67	17.04	16.04	8.64
MCN31422P	865.07	903.12	23.03	14.48	47.01
MCN31421P	869.98	888.70	15.37	14.67	23.18
MCN31424P	881.67	885.51	18.91	18.47	7.28
% Saturation					
MCN31423P	116.54	117.38	2.68	2.54	1.14
MCN31422P	114.52	119.55	3.33	2.24	6.23
MCN31421P	115.17	117.64	2.32	2.34	3.07
MCN31424P	116.71	117.22	2.96	2.86	0.96

**Table 31. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN31423P	100	100	100	100
MCN31422P	92.93	63.25	63.25	63.25
MCN31421P	98.59	77.03	88.69	89.05
MCN31424P	100	100	100	100

**Table 32. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN30661P	17.33	17.80	0.37	0.85	0.84
MCN30663P	17.24	17.34	0.35	0.33	0.30
Concentration (mg/l)					
MCN30661P	30.00	31.16	0.42	0.65	1.42
MCN30663P	30.52	31.01	0.43	0.41	0.53
Gas Pressure (mmHg)					
MCN30661P	861.47	902.68	13.69	14.41	44.43
MCN30663P	874.53	890.53	14.35	14.67	18.03
% Saturation					
MCN30661P	114.04	119.49	2.27	1.97	5.86
MCN30663P	115.77	117.89	2.38	2.31	2.38

**Table 33. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN30661P	81.27	51.24	42.76	43.82
MCN30663P	100	100	100	100

**Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

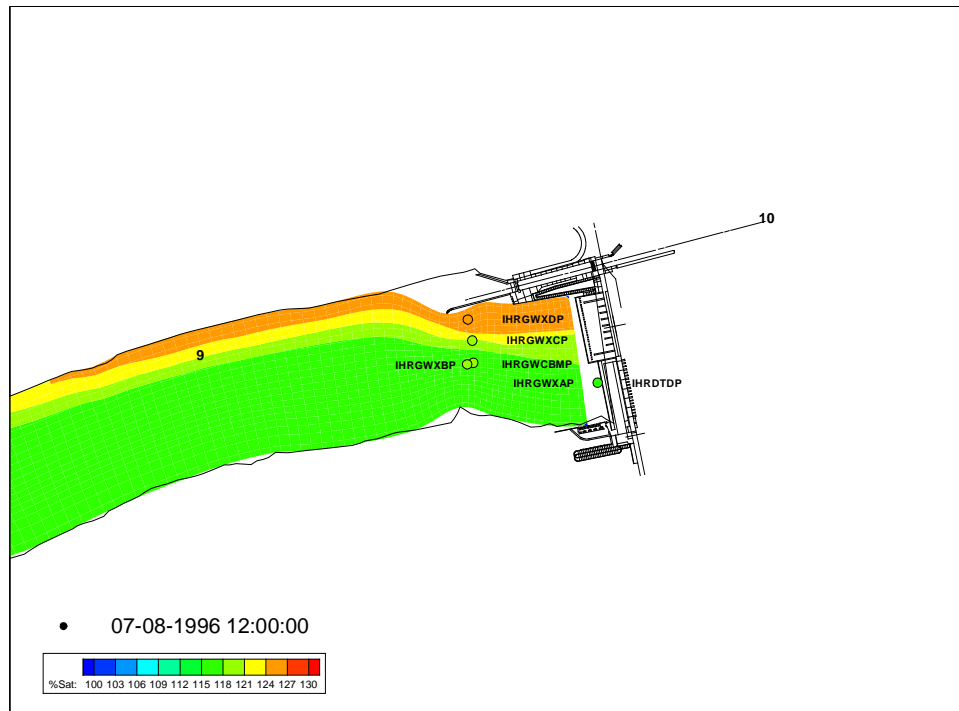
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_MCQW	18.94	17.03	0.52	1.78	2.71
FMS_MCQO	17.82	17.36	0.70	1.88	2.22
Concentration (mg/l)					
FMS_MCQW	30.28	31.69	0.33	1.14	1.93
FMS_MCQO	30.33	31.47	0.23	1.05	1.60
Gas Pressure (mmHg)					
FMS_MCQW	896.46	903.28	8.27	14.94	18.27
FMS_MCQO	878.91	902.93	13.50	13.59	28.08
% Saturation					
FMS_MCQW	118.43	119.73	1.48	1.84	2.69
FMS_MCQO	116.12	119.69	1.64	1.69	4.12

**Table 35. Statistical summary of measurements and simulations for the Summer 1996 pool study (TM-BC).**

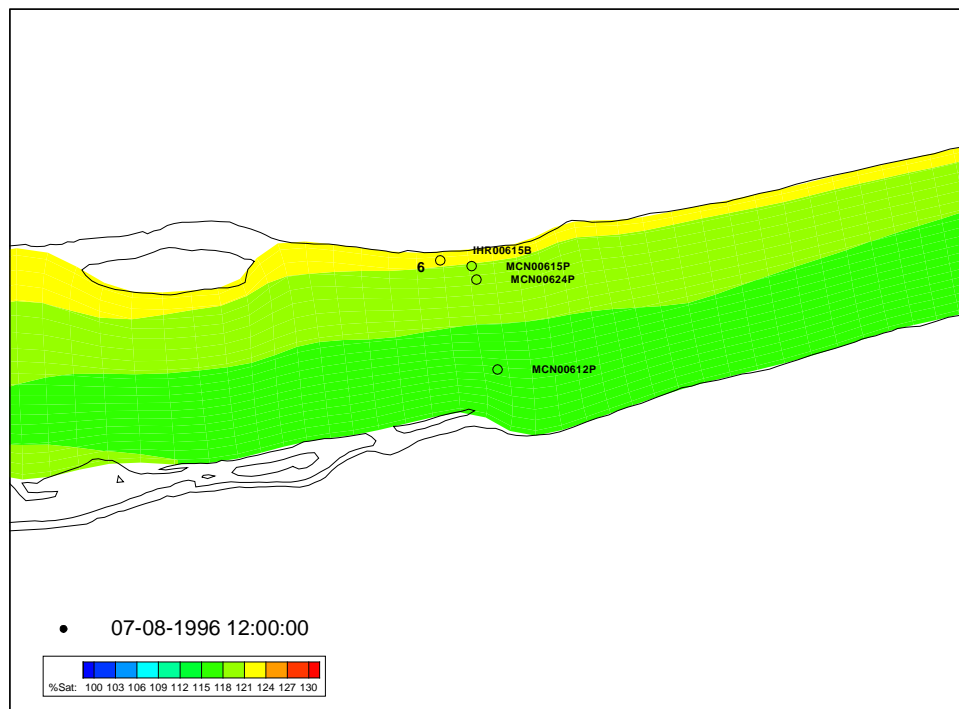
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Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_MCQW	25.87	36.36	100	100
FMS_MCQO	89.51	65.73	85.31	72.03

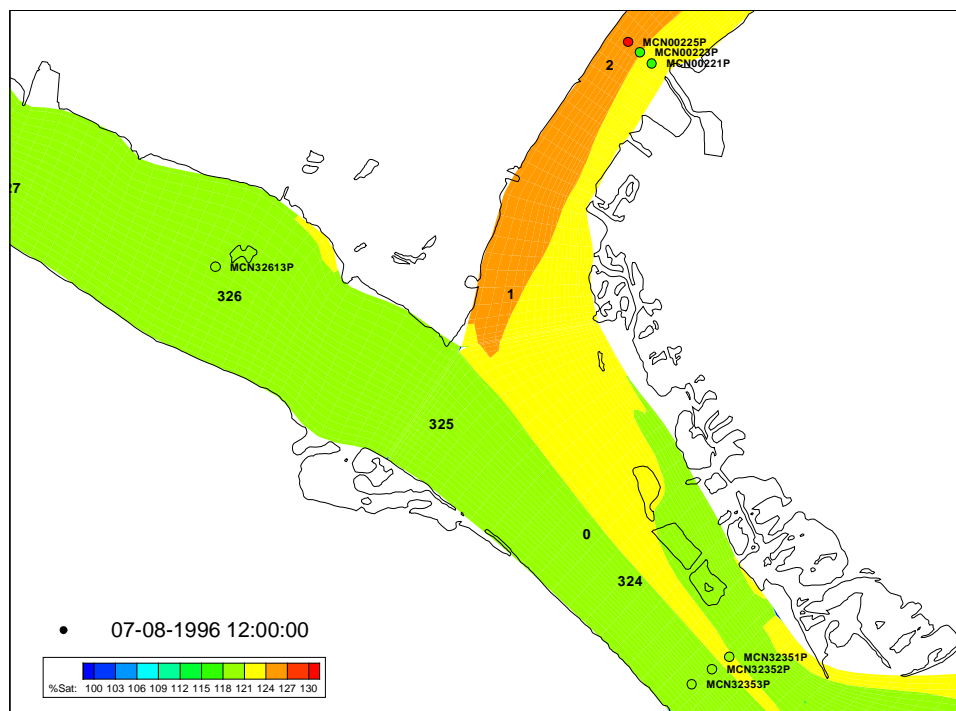
**Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**



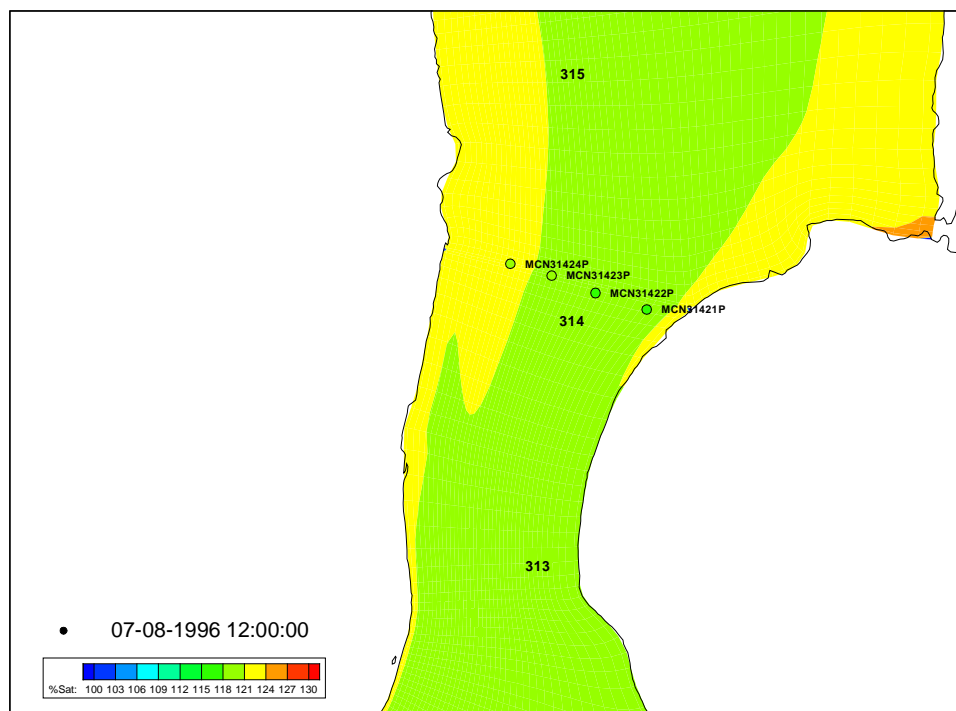
**Figure 85. Total dissolved gas simulated distribution near Ice Harbor Dam on 7-8-1996 (TM-BC). The monitors are color coded to their measured saturation.**



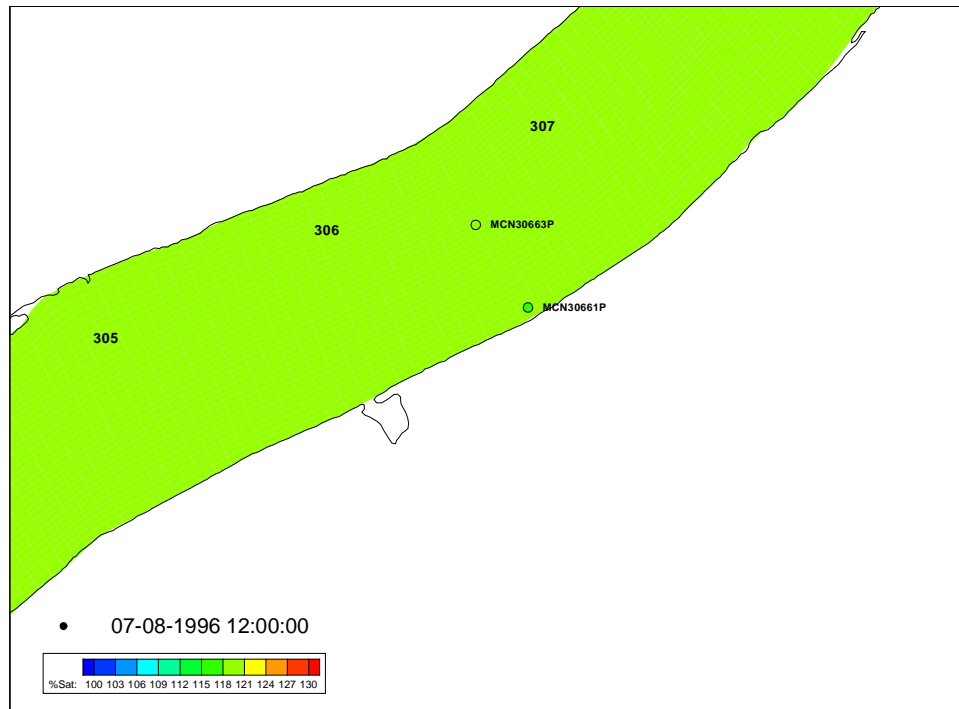
**Figure 86. Total dissolved gas simulated distribution near Snake River Mile 6 on 7-8-1996 (TM-BC). The monitors are color coded to their measured saturation.**



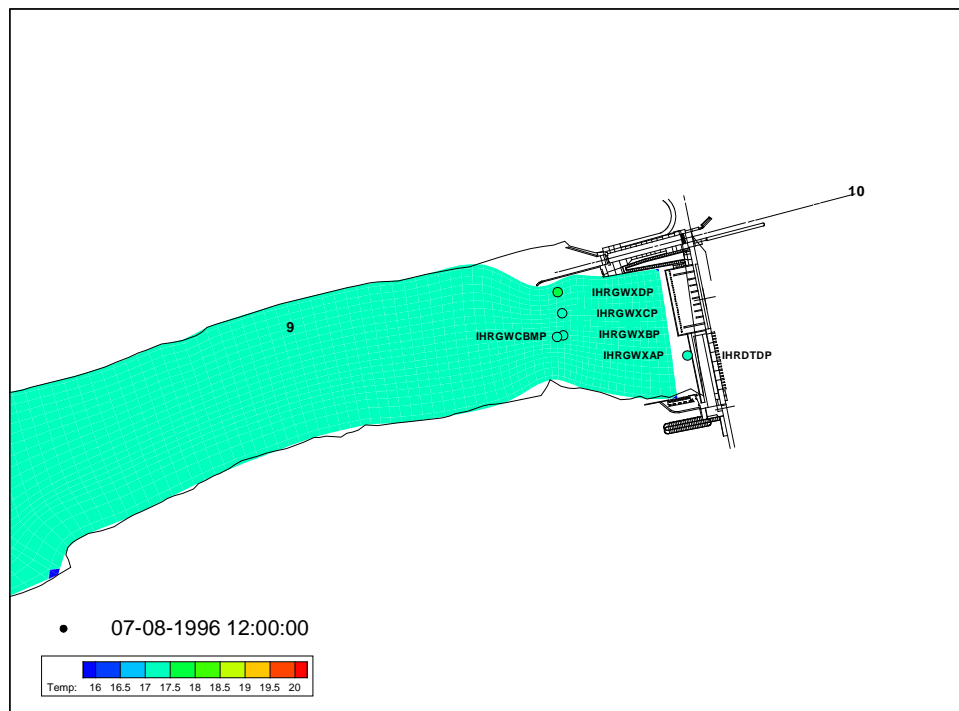
**Figure 87. Total dissolved gas simulated distribution at the confluence of the Columbia and Snake Rivers on 7-8-1996 (TM-BC). The monitors are color coded to their measured saturation.**



**Figure 88. Total dissolved gas simulated distribution near Columbia River Mile 314 on 7-8-1996 (TM-BC). The monitors are color coded to their measured saturation.**

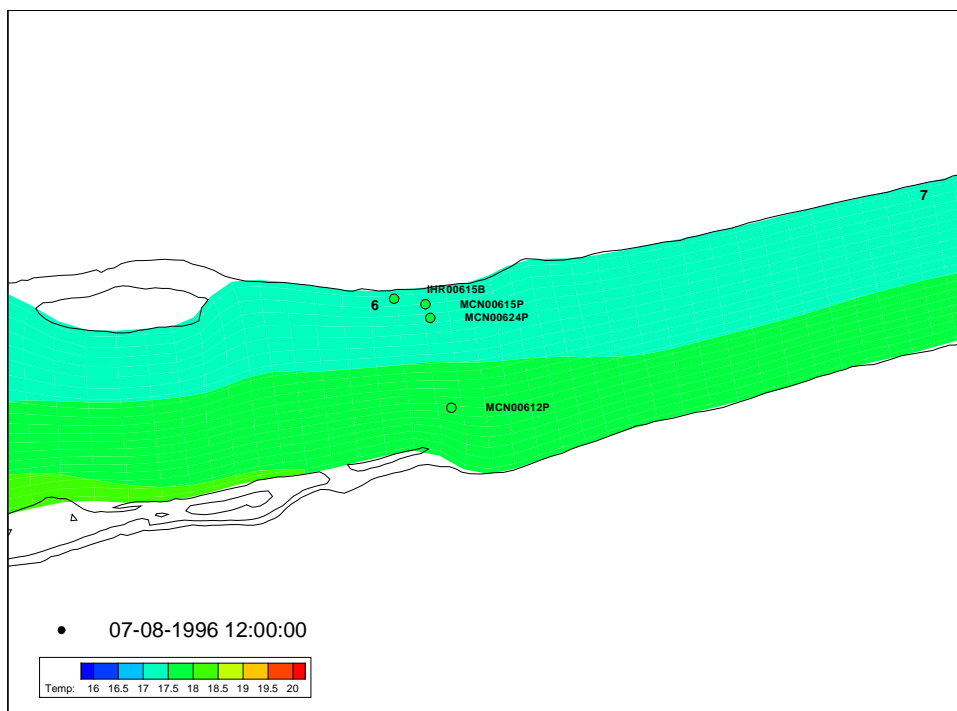


**Figure 89. Total dissolved gas simulated distribution near Columbia River Mile 306.5 on 7-8-1996 (TM-BC). The monitors are color coded to their measured saturation.**

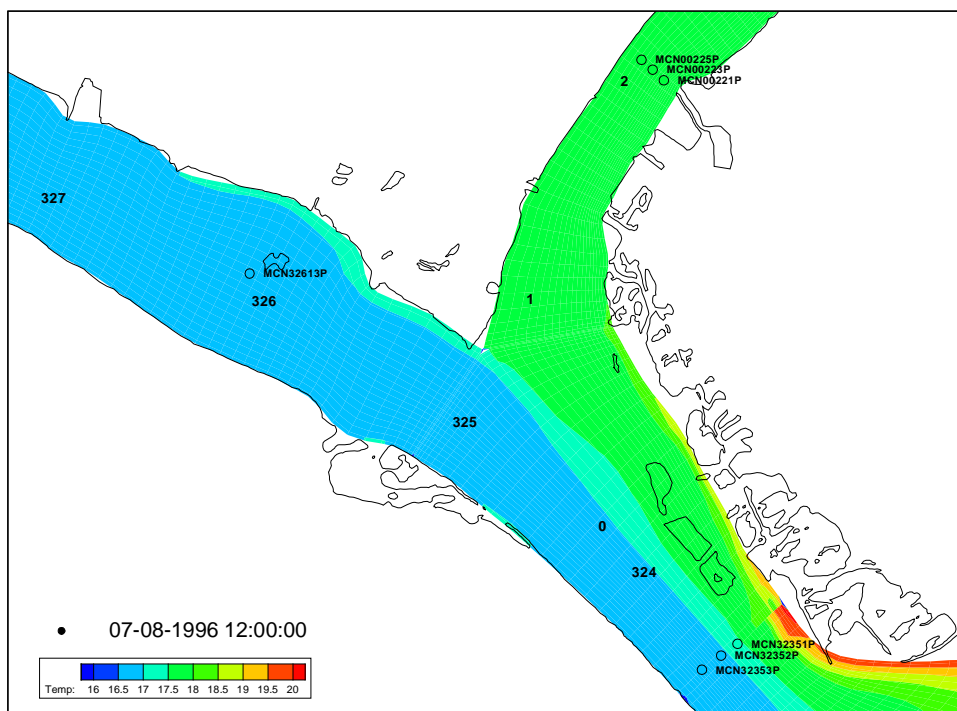


**Figure 90. Simulated temperature distribution near Ice Harbor Dam 7-8-1996 (TM-BC). The monitors are color coded to their measured temperature.**

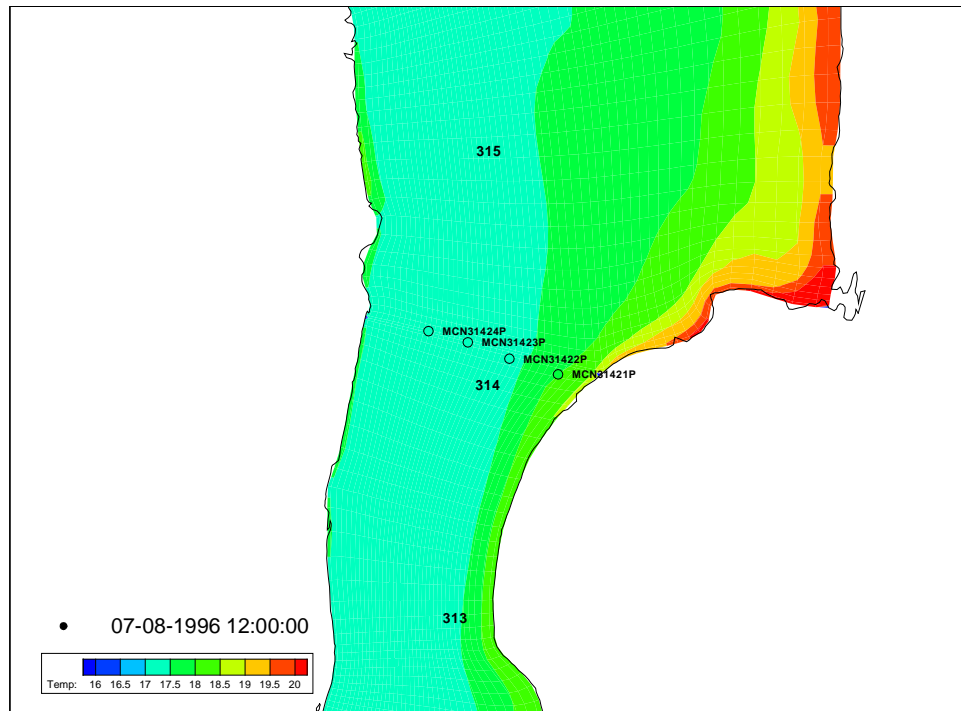




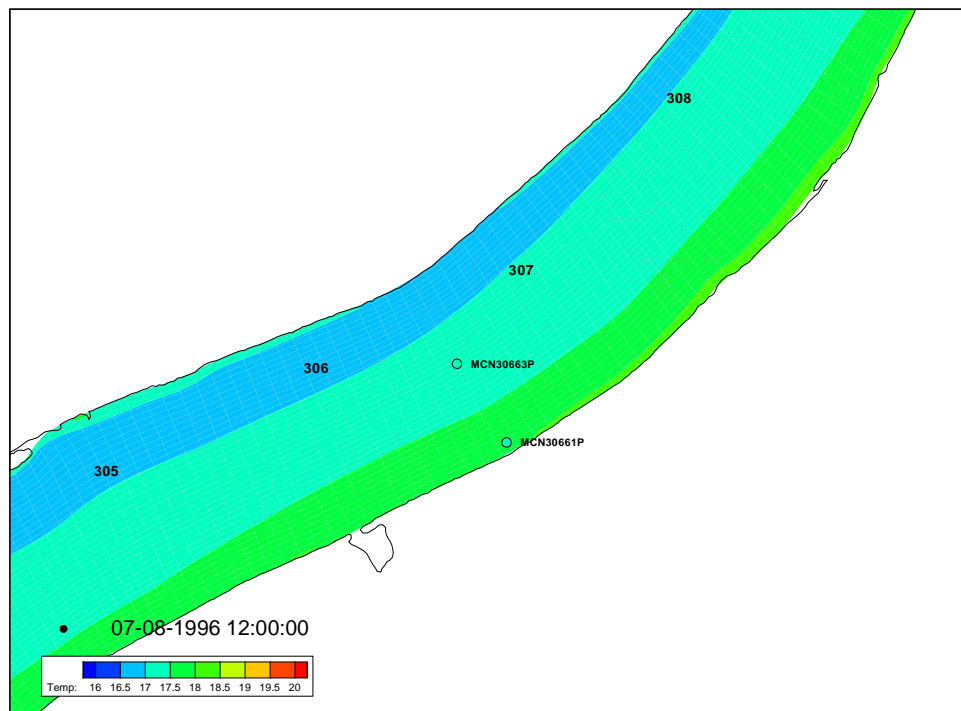
**Figure 91. Simulated temperature distribution near Snake River Mile 6 7-8-1996 (TM-BC). The monitors are color coded to their measured temperature.**



**Figure 92. Simulated temperature distribution at the confluence of the Columbia and Snake Rivers on 7-8-1996 (TM-BC). The monitors are color coded to their measured temperature.**



**Figure 93. Simulated temperature distribution near Columbia River Mile 314 7-8-1996 (TM-BC). The monitors are color coded to their measured temperature.**

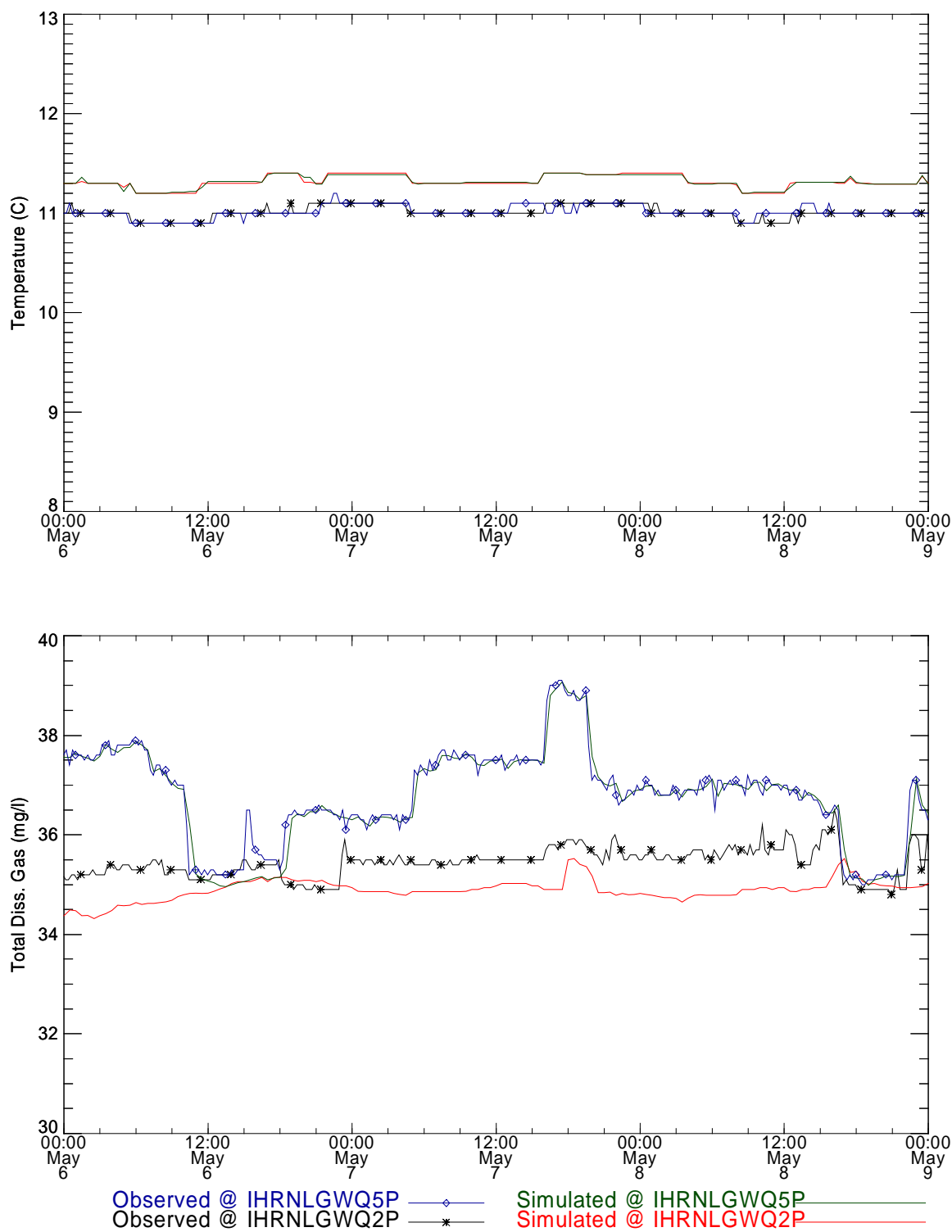


**Figure 94. Simulated temperature distribution near Columbia River Mile 306.5 7-8-1996 (TM-BC). The monitors are color coded to their measured temperature.**

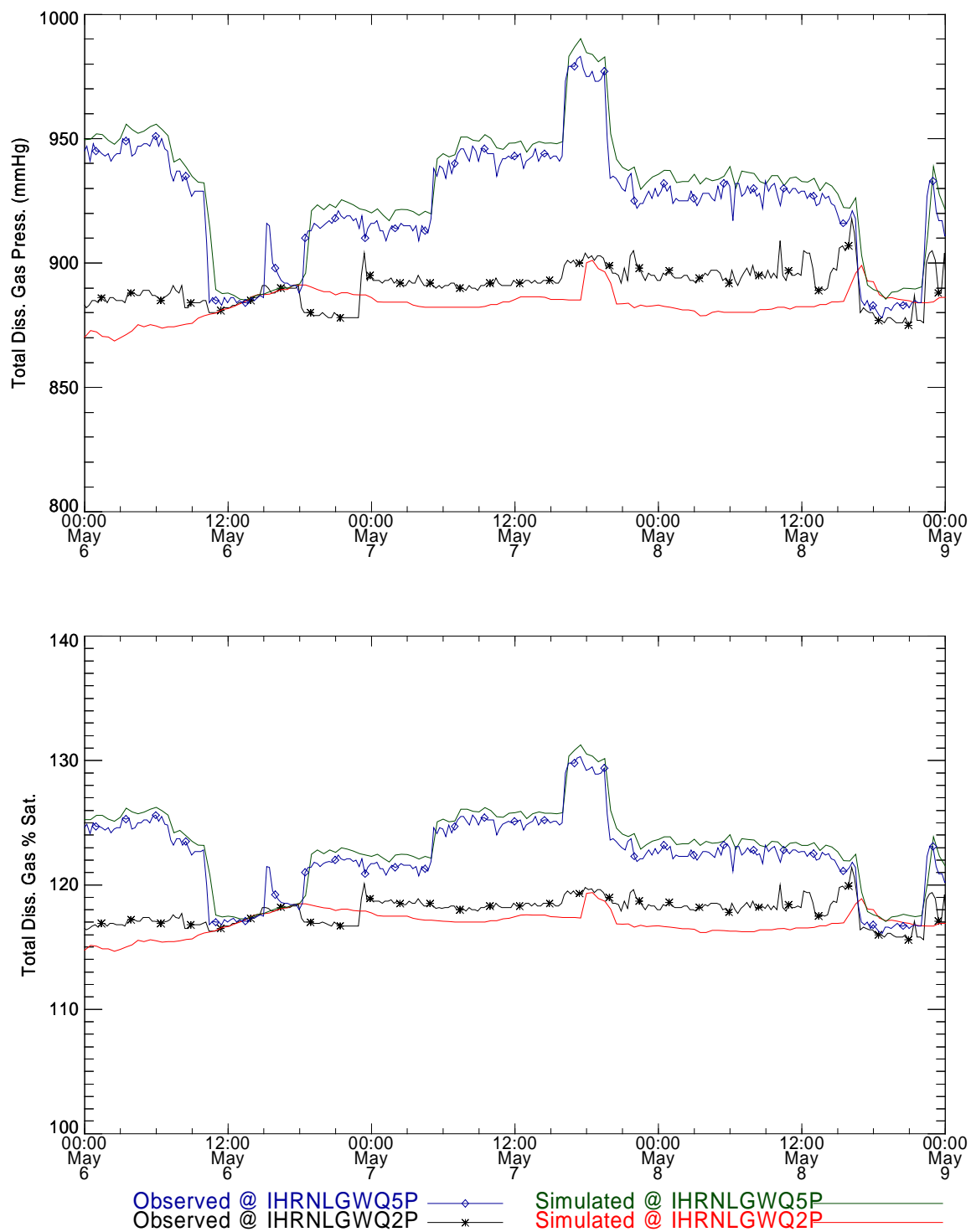
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### ***1.4.2 1996 Spring Simulation***

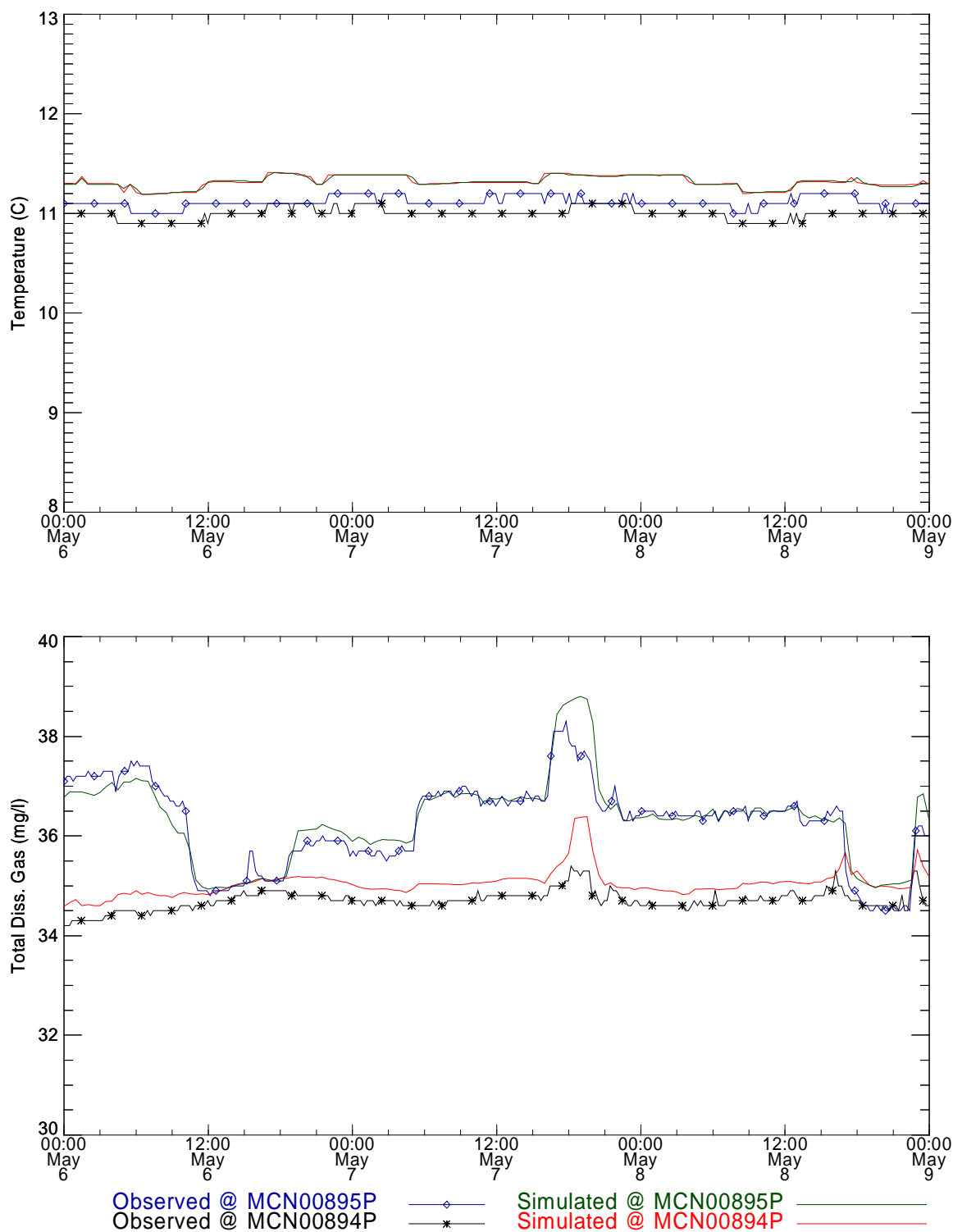
Comparisons between the measurements and simulations using an upstream boundary condition developed from the furthest upstream gas monitor and the gas monitor located at the draft tube are shown in the Figures below.



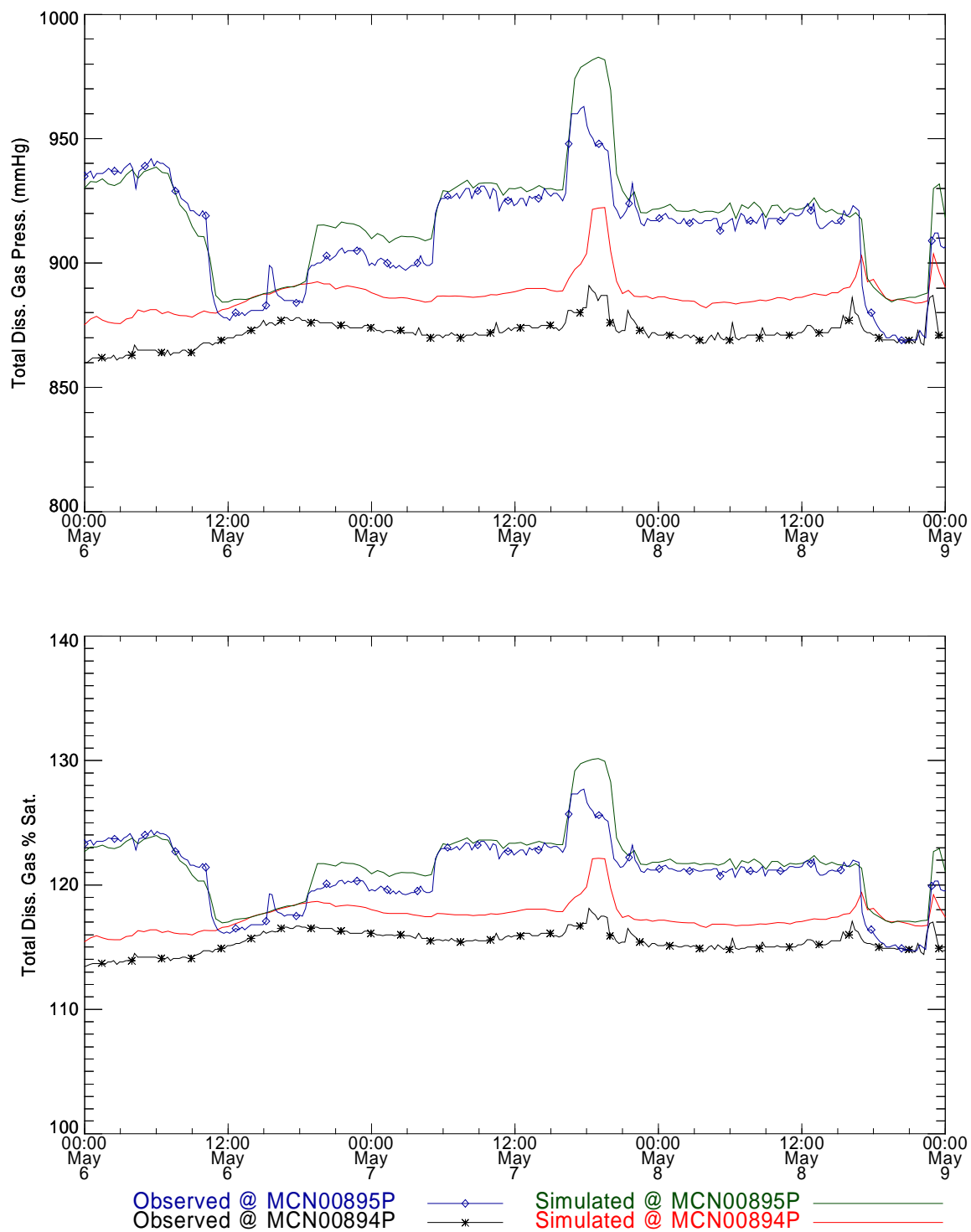
**Figure 95. Temperature and total dissolved gas time series comparisons near Ice Harbor Dam for the Spring 1996 pool study.**



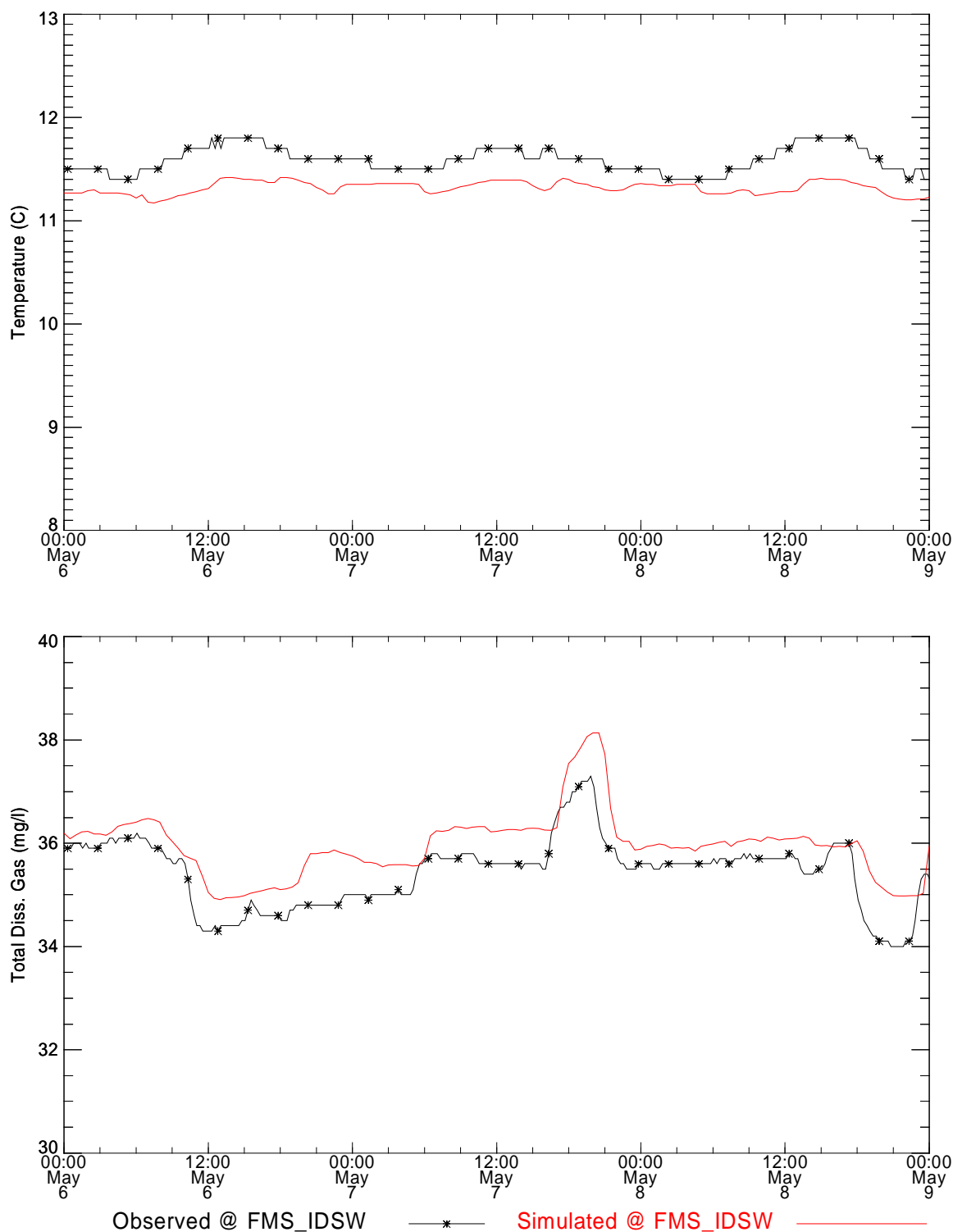
**Table 37. Total dissolved gas time series comparisons near Ice Harbor Dam for the Spring 1996 pool study.**



**Figure 96. Temperature and total dissolved gas time series comparisons near Snake River Mile 8.9 for the Spring 1996 pool study.**

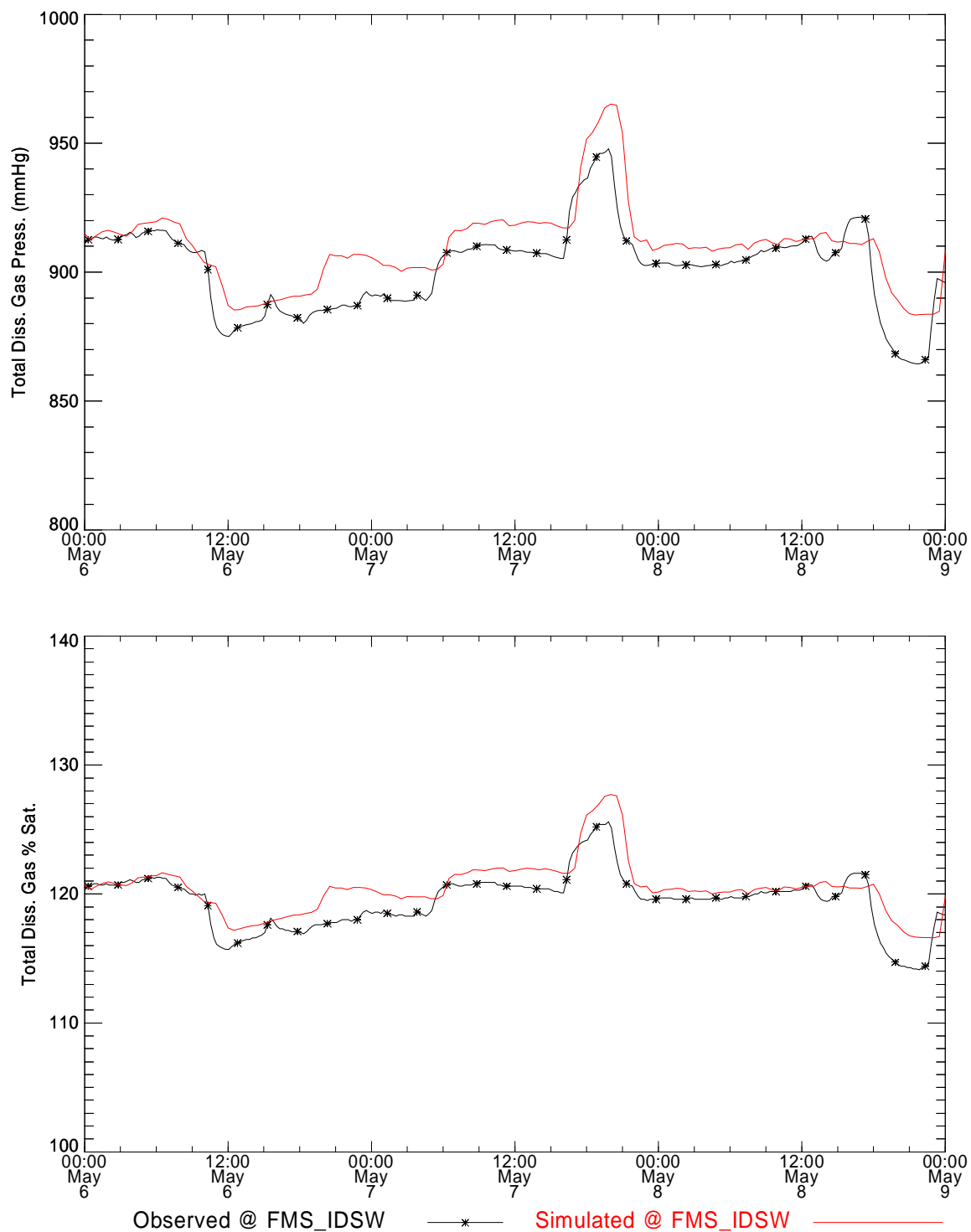


**Figure 97. Total dissolved gas time series comparisons near Snake River Mile 8.9 for the Spring 1996 pool study.**

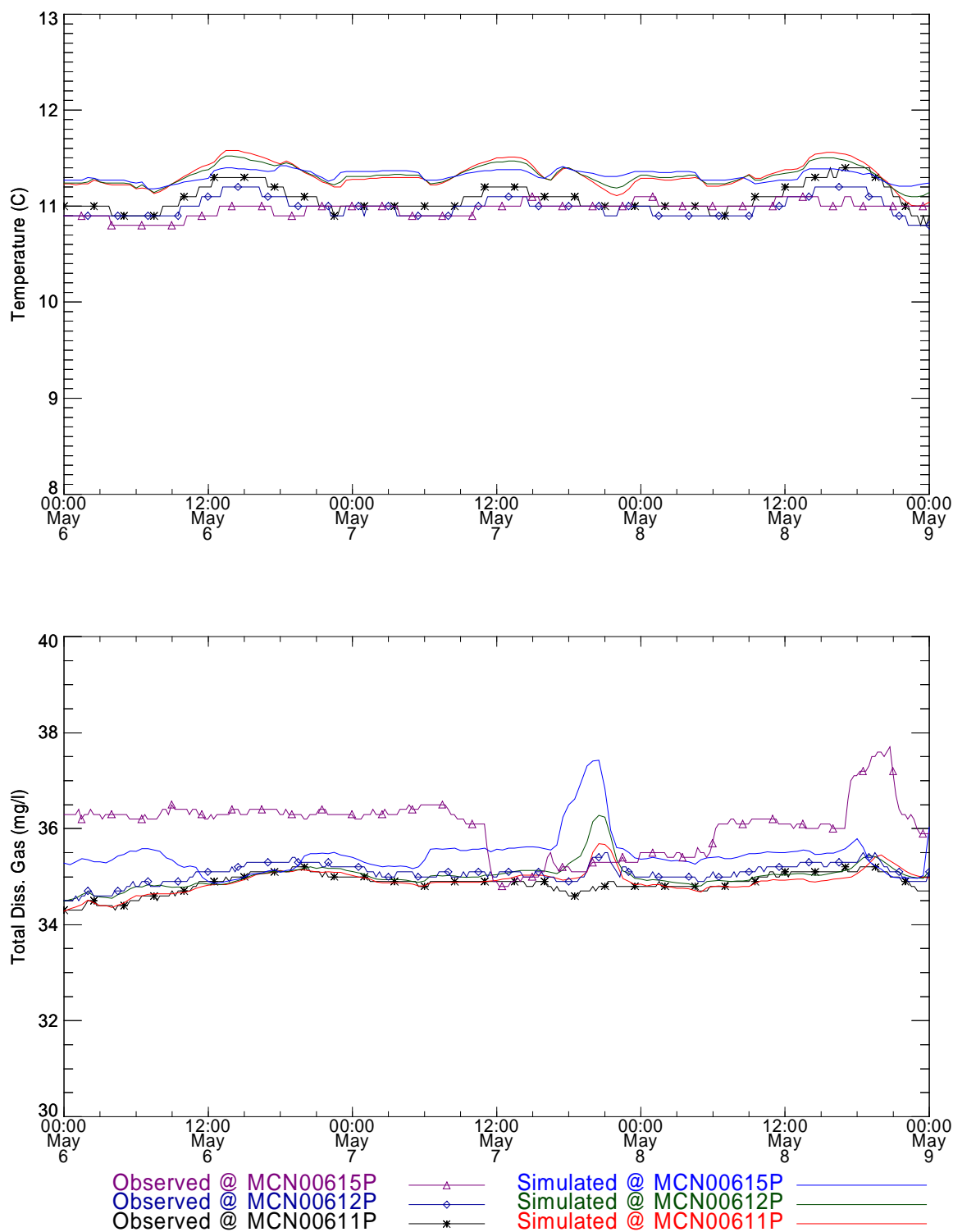


**Figure 98. Temperature and total dissolved gas time series comparisons near Ice Harbor Fixed Monitor for the Spring 1996 pool study.**

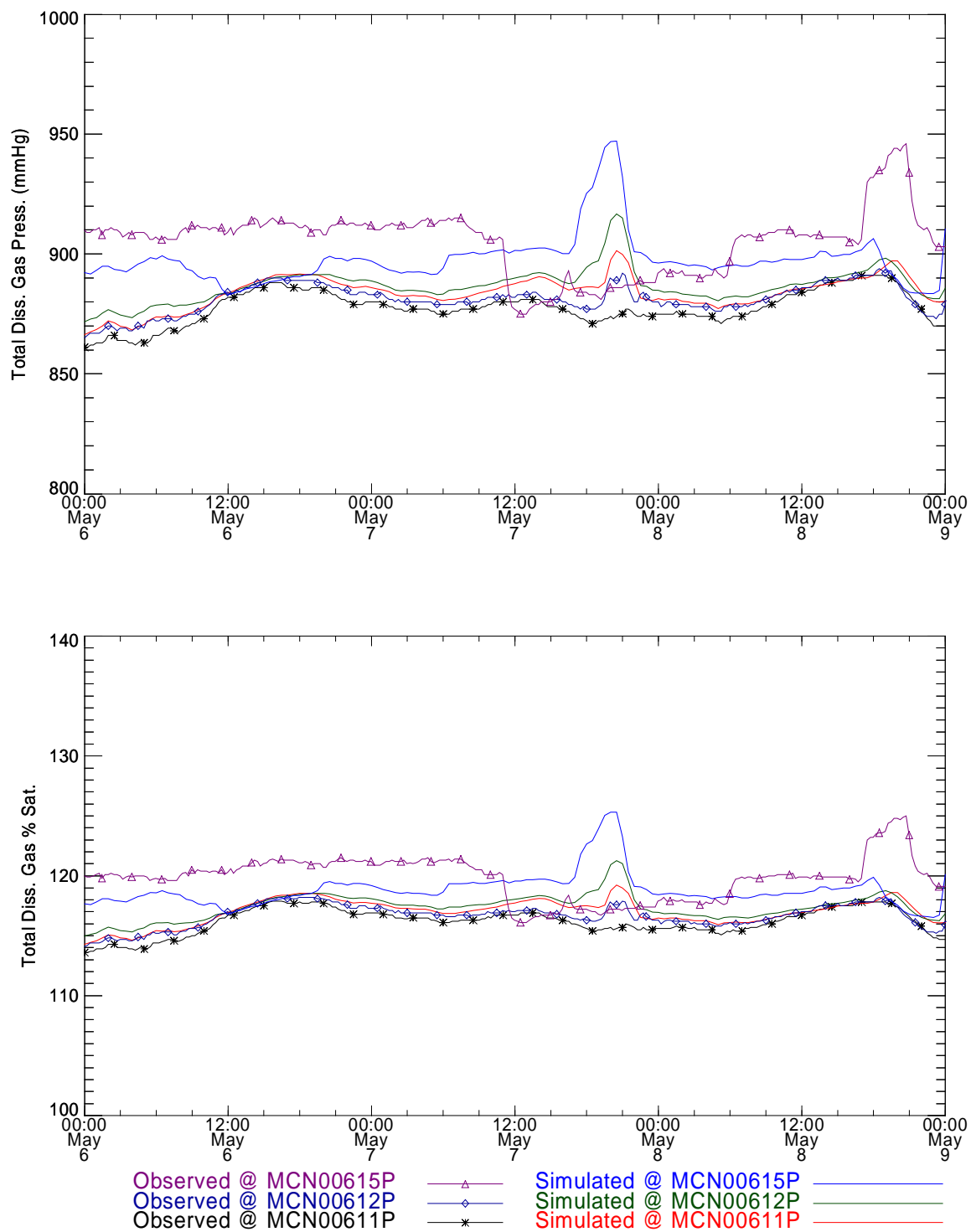




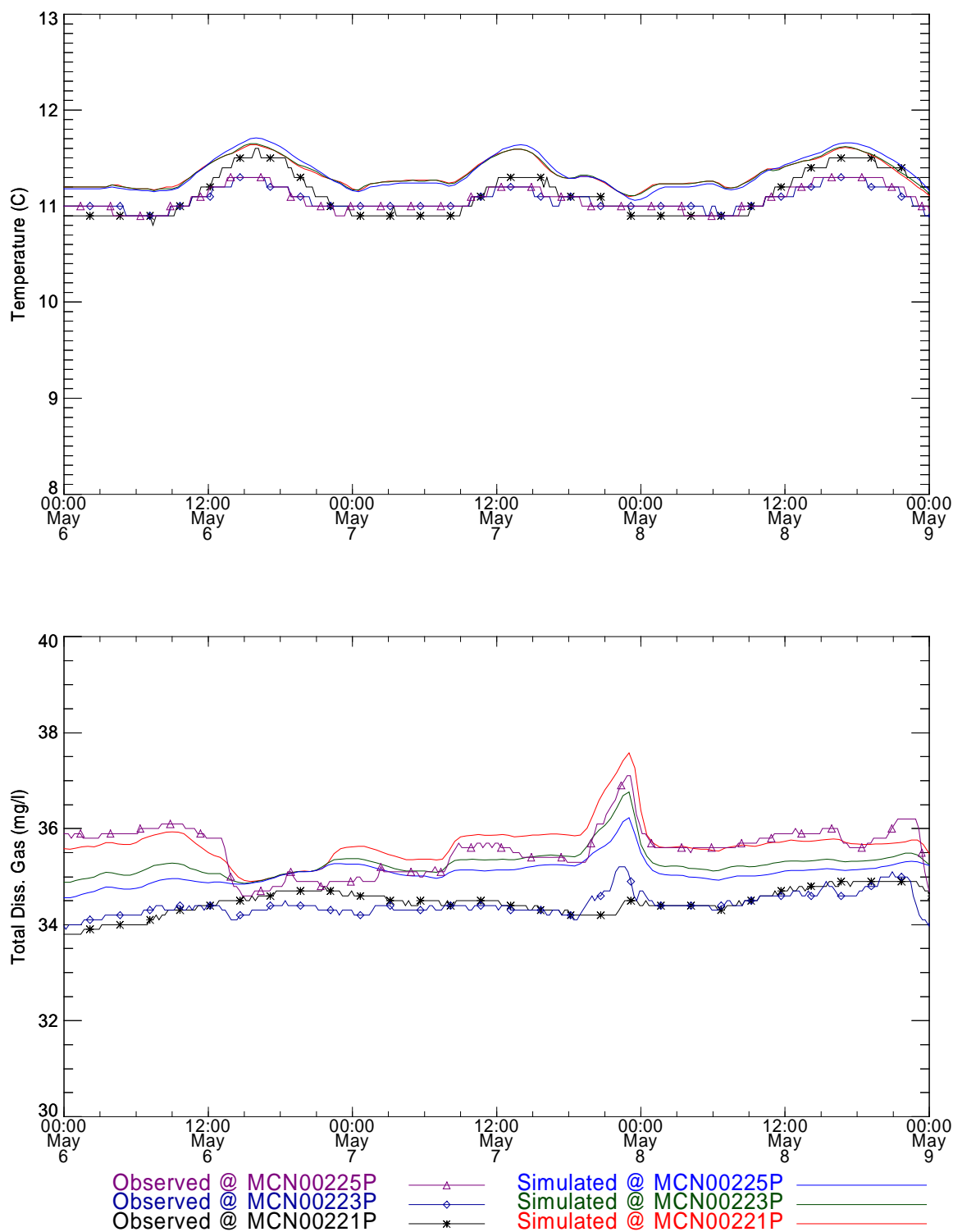
**Figure 99. Total dissolved gas time series comparisons near Ice Harbor Fixed Monitor for the Spring 1996 pool study.**



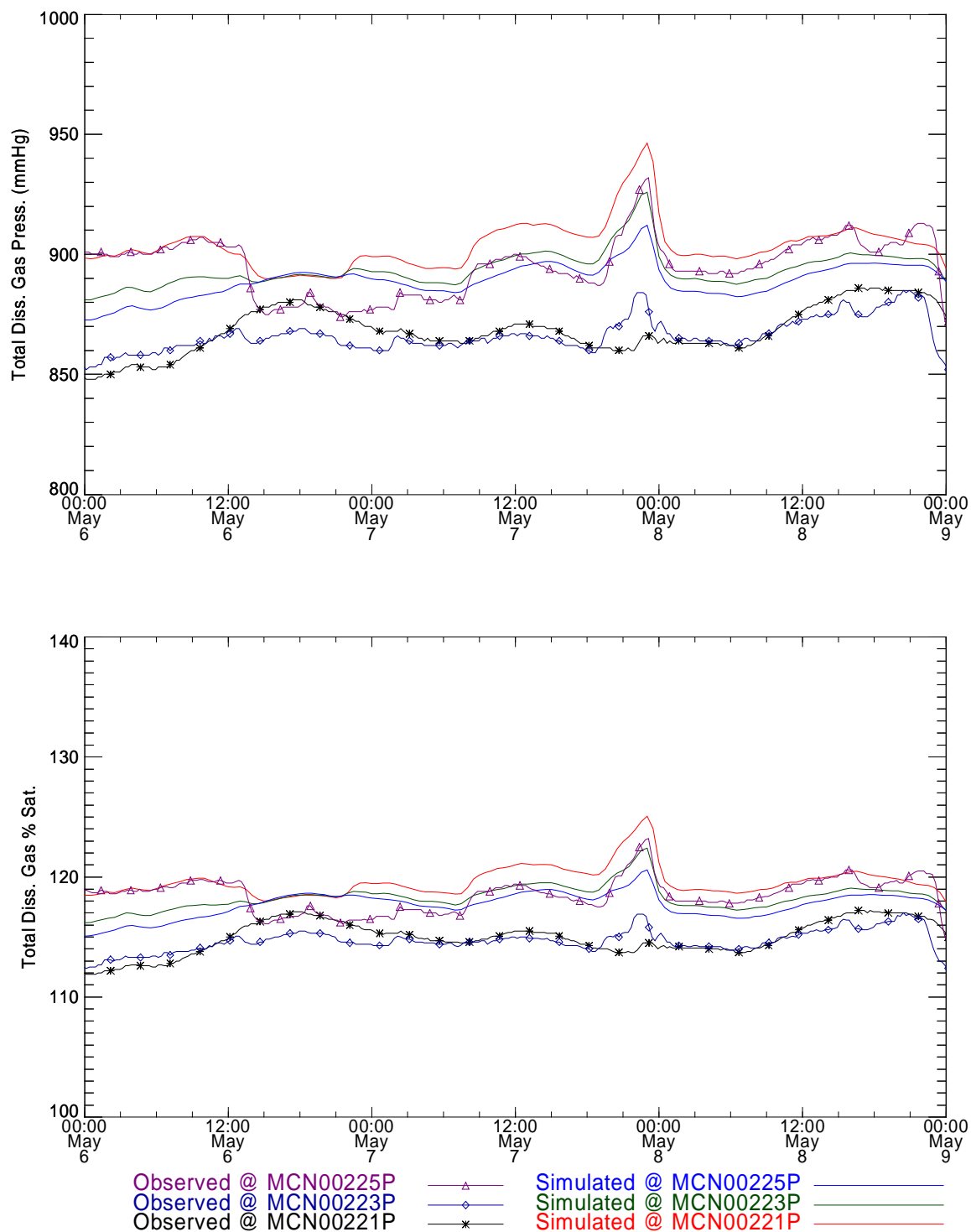
**Figure 100. Temperature and total dissolved gas time series comparisons near Snake River Mile 6.1 for the Spring 1996 pool study.**



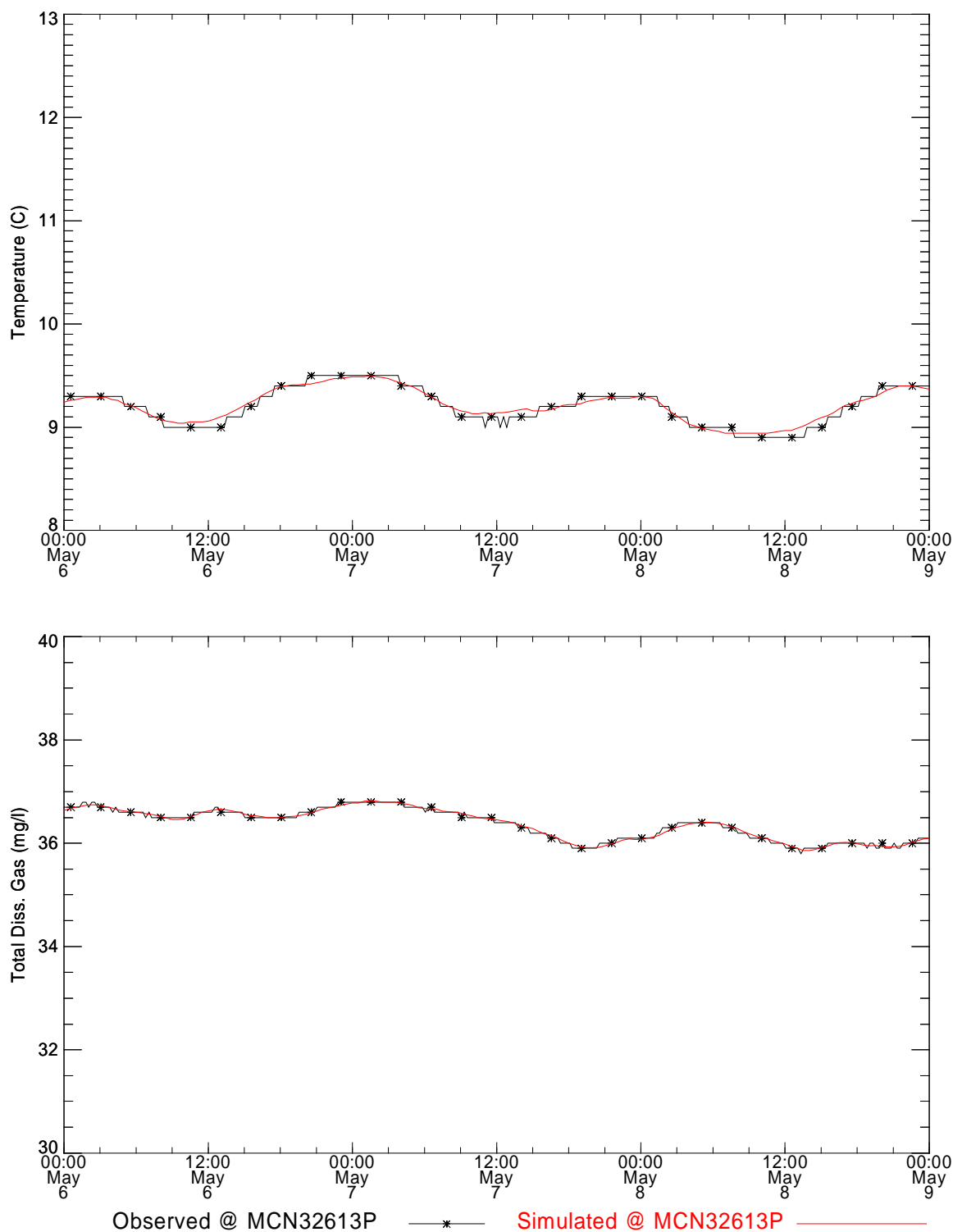
**Figure 101. Total dissolved gas time series comparisons near Snake River Mile 6.1 for the Spring 1996 pool study.**



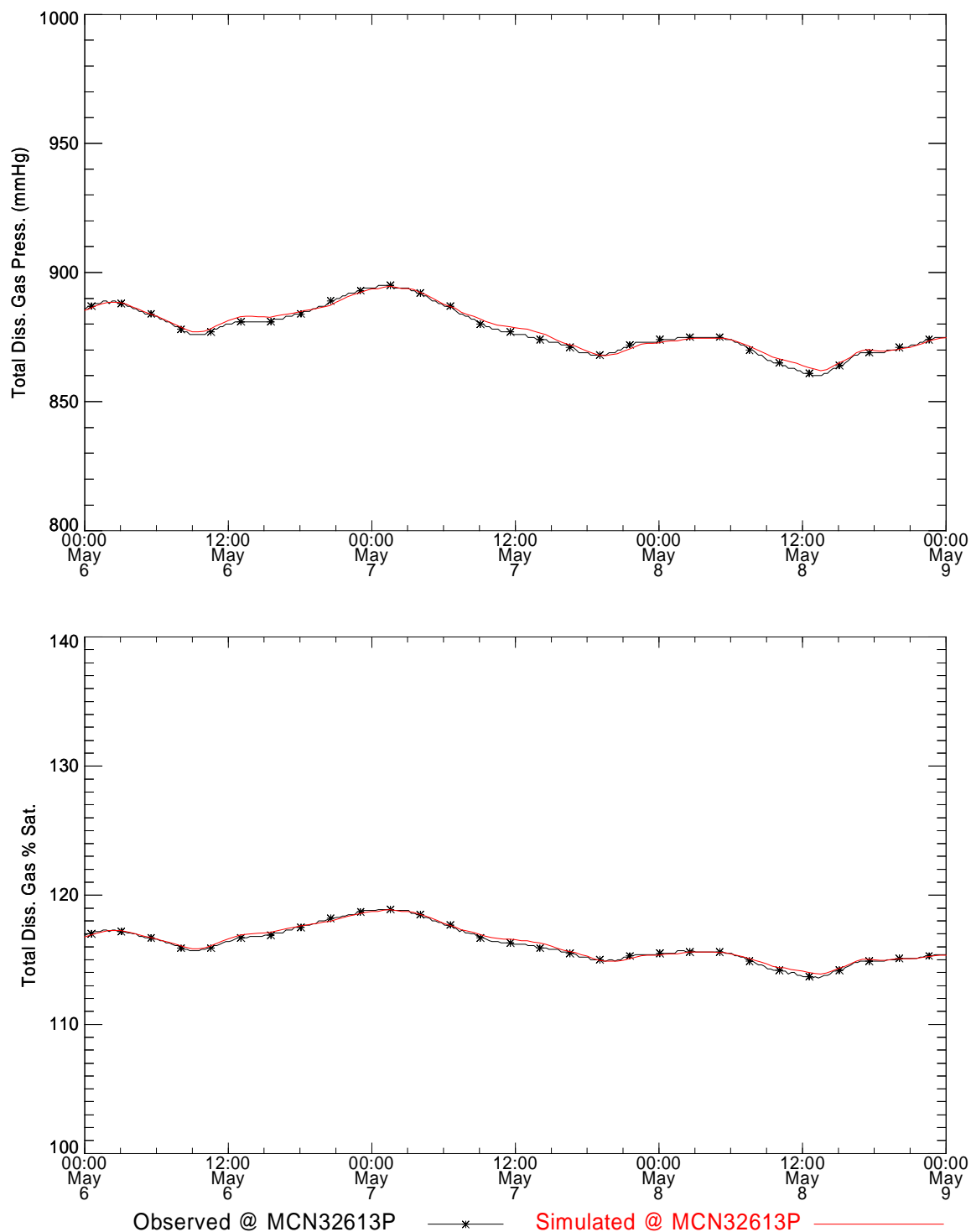
**Figure 102. Temperature and total dissolved gas time series comparisons near Snake River Mile 2.2 for the Spring 1996 pool study.**



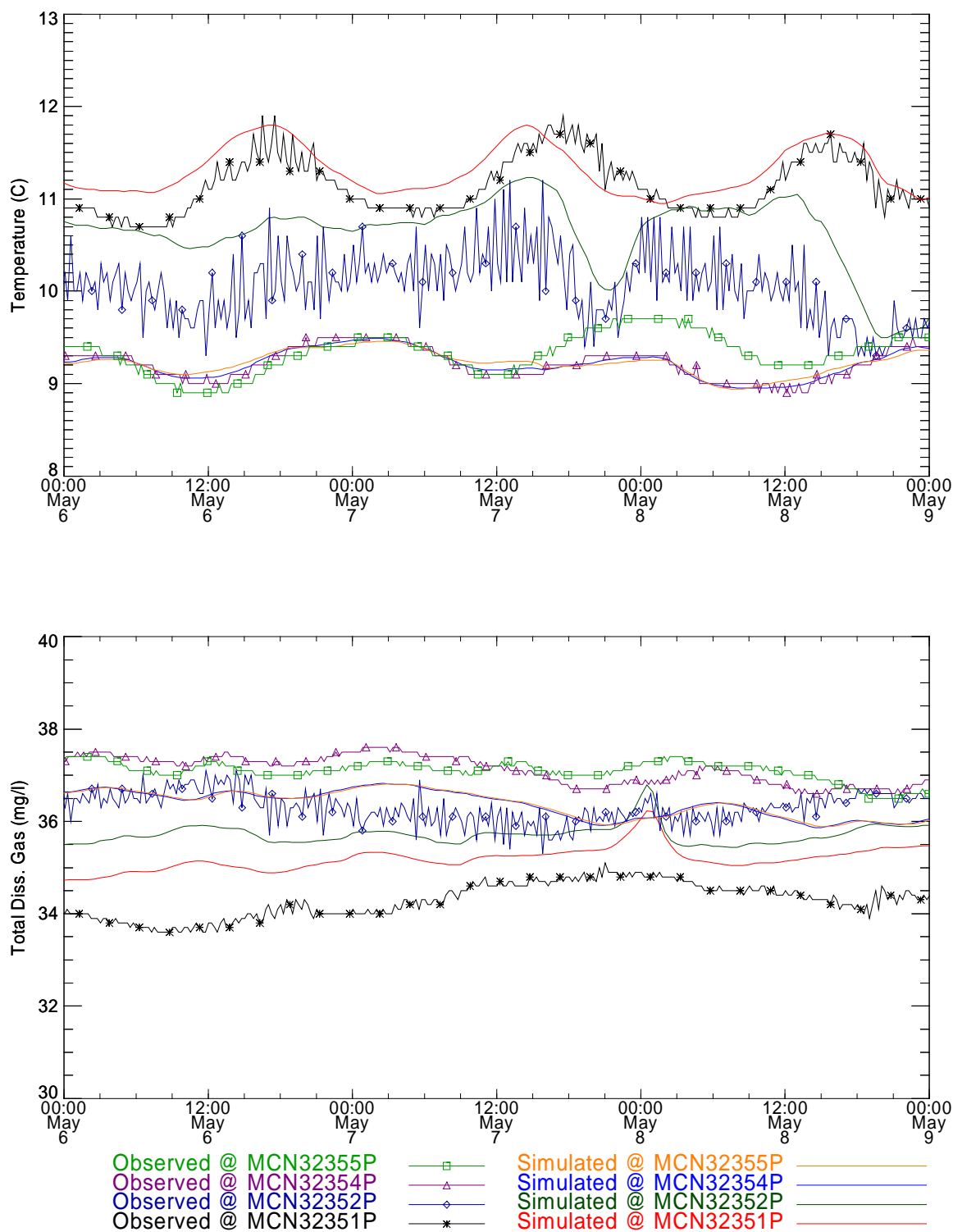
**Figure 103. Total dissolved gas time series comparisons near Snake River Mile 2.2 for the Spring 1996 pool study.**



**Figure 104. Temperature and total dissolved gas concentration at Columbia River Mile 326.1. Note that this monitor supplied the model boundary conditions at Clover Island.**

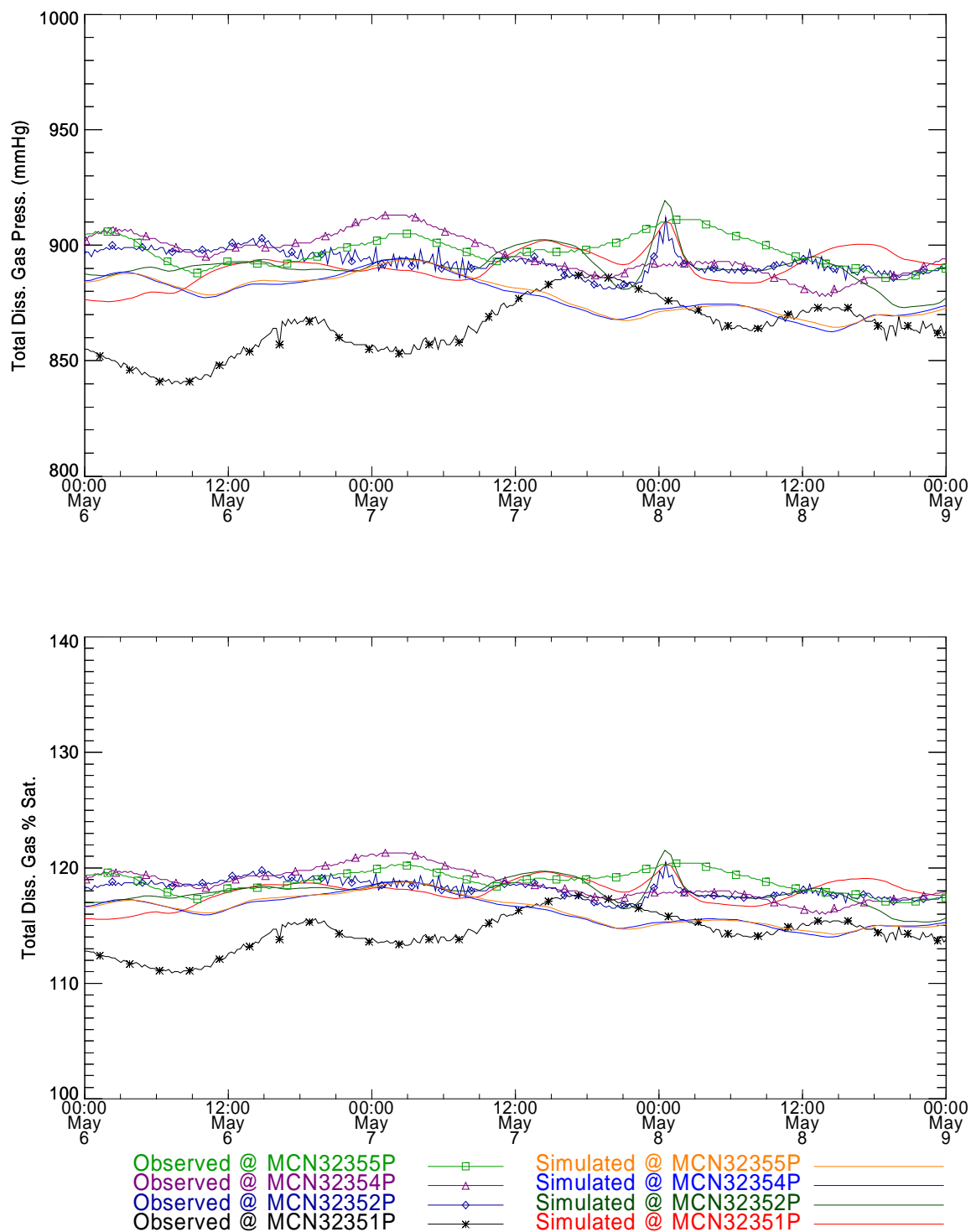


**Figure 105. Total dissolved gas concentration at Columbia River Mile 326.1. Note that this monitor supplied the model boundary conditions at Clover Island.**

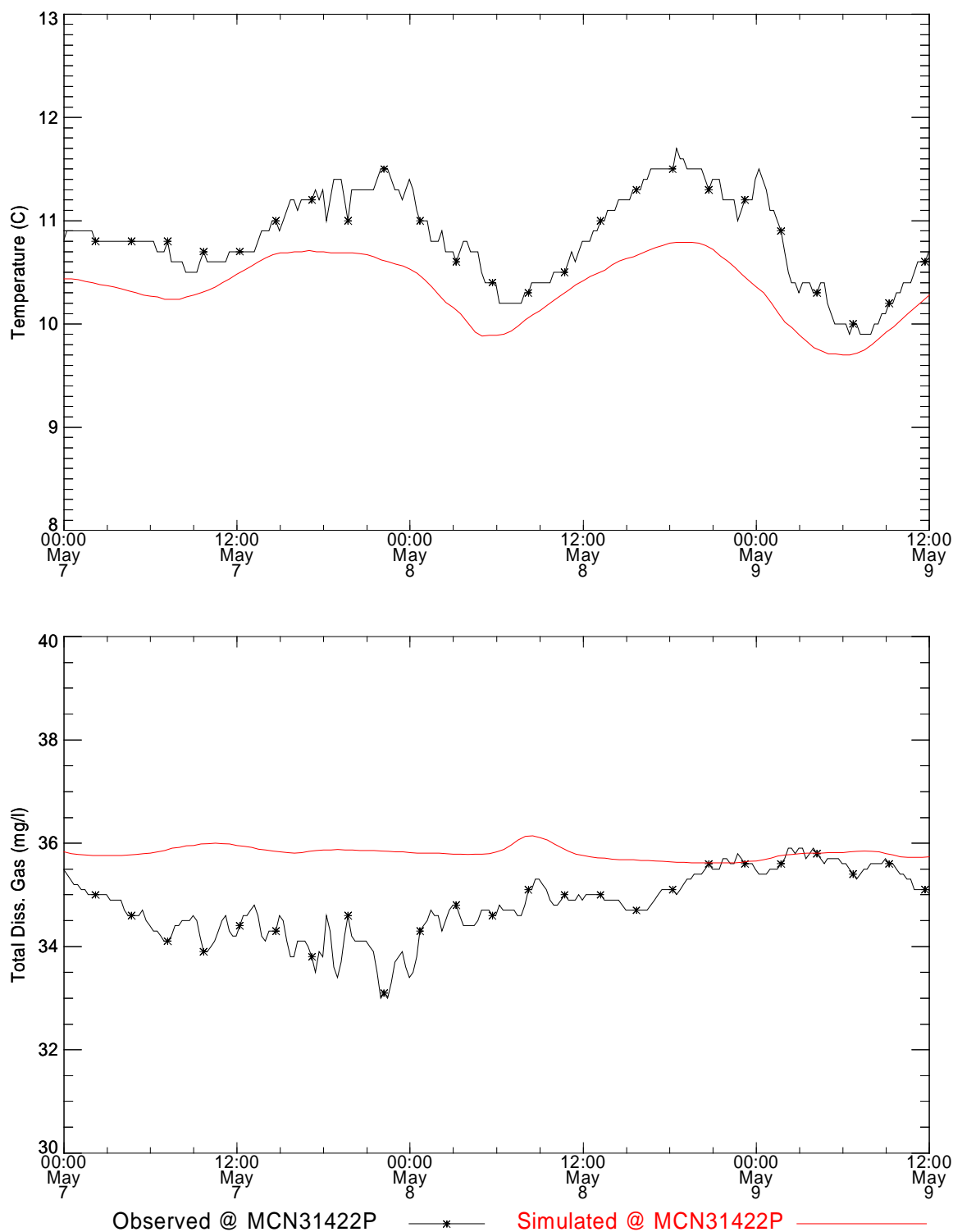


**Figure 106. Temperature and total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Spring 1996 pool study.**

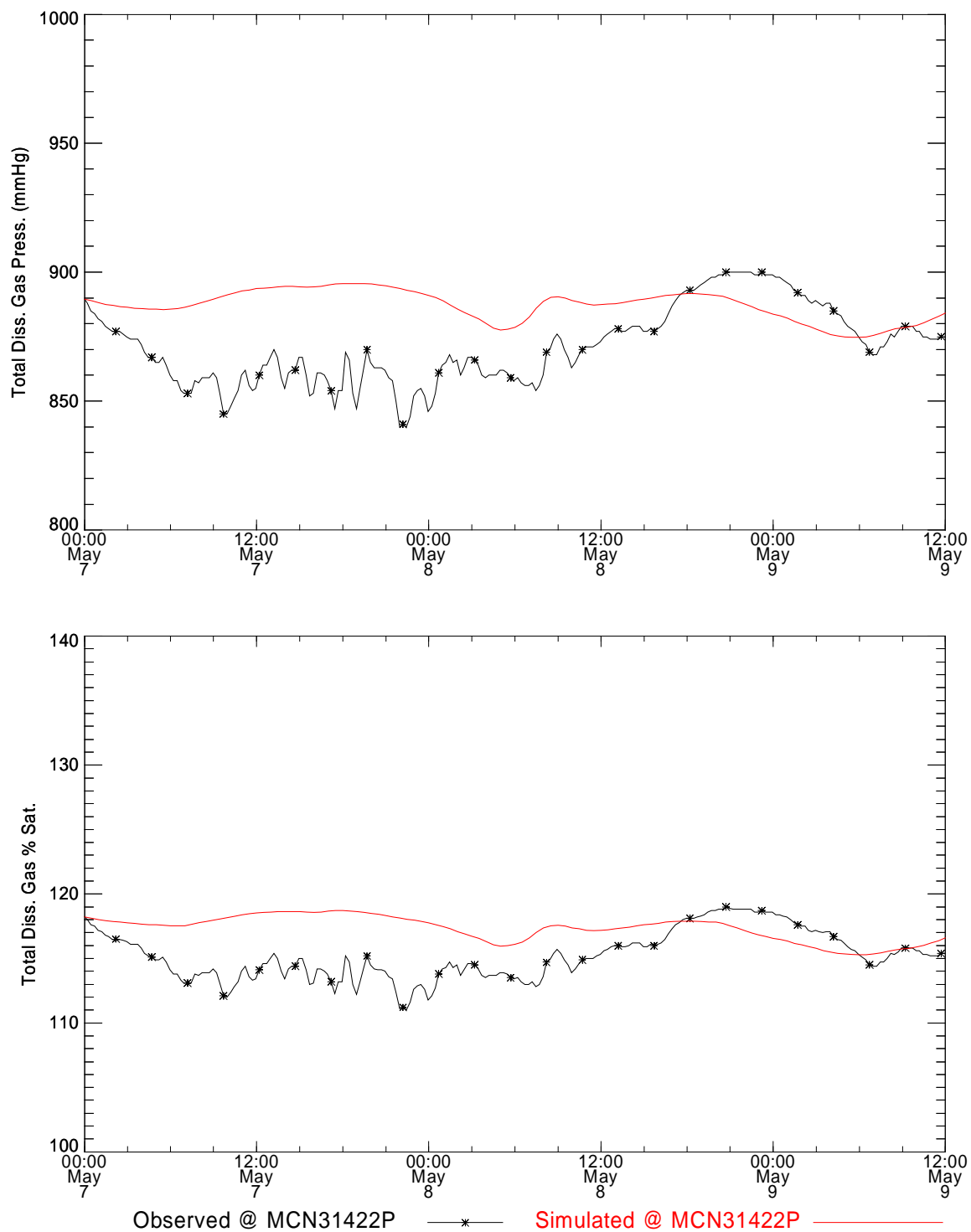




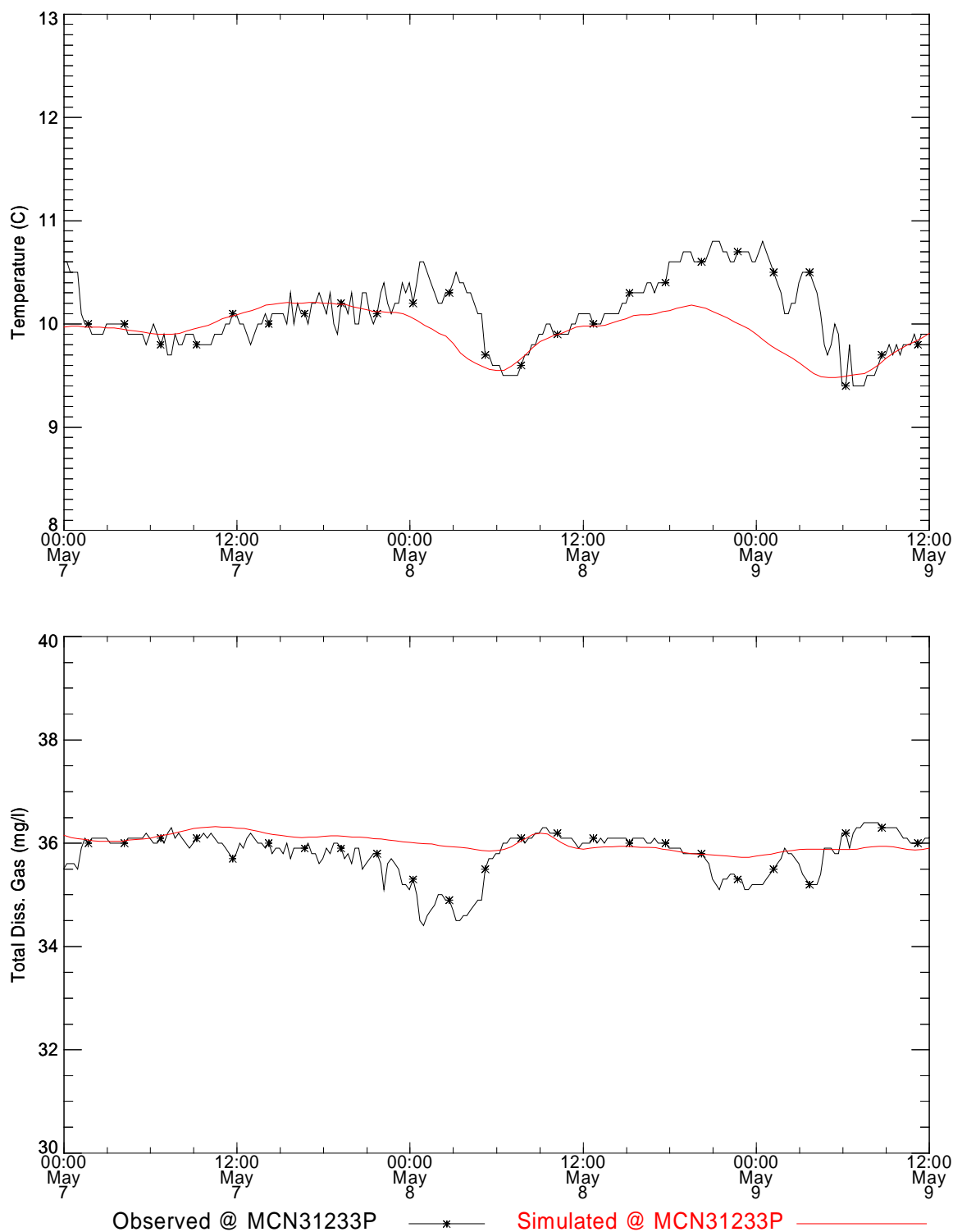
**Figure 107. Total dissolved gas time series comparisons near Columbia River Mile 323.5 for the Spring 1996 pool study.**



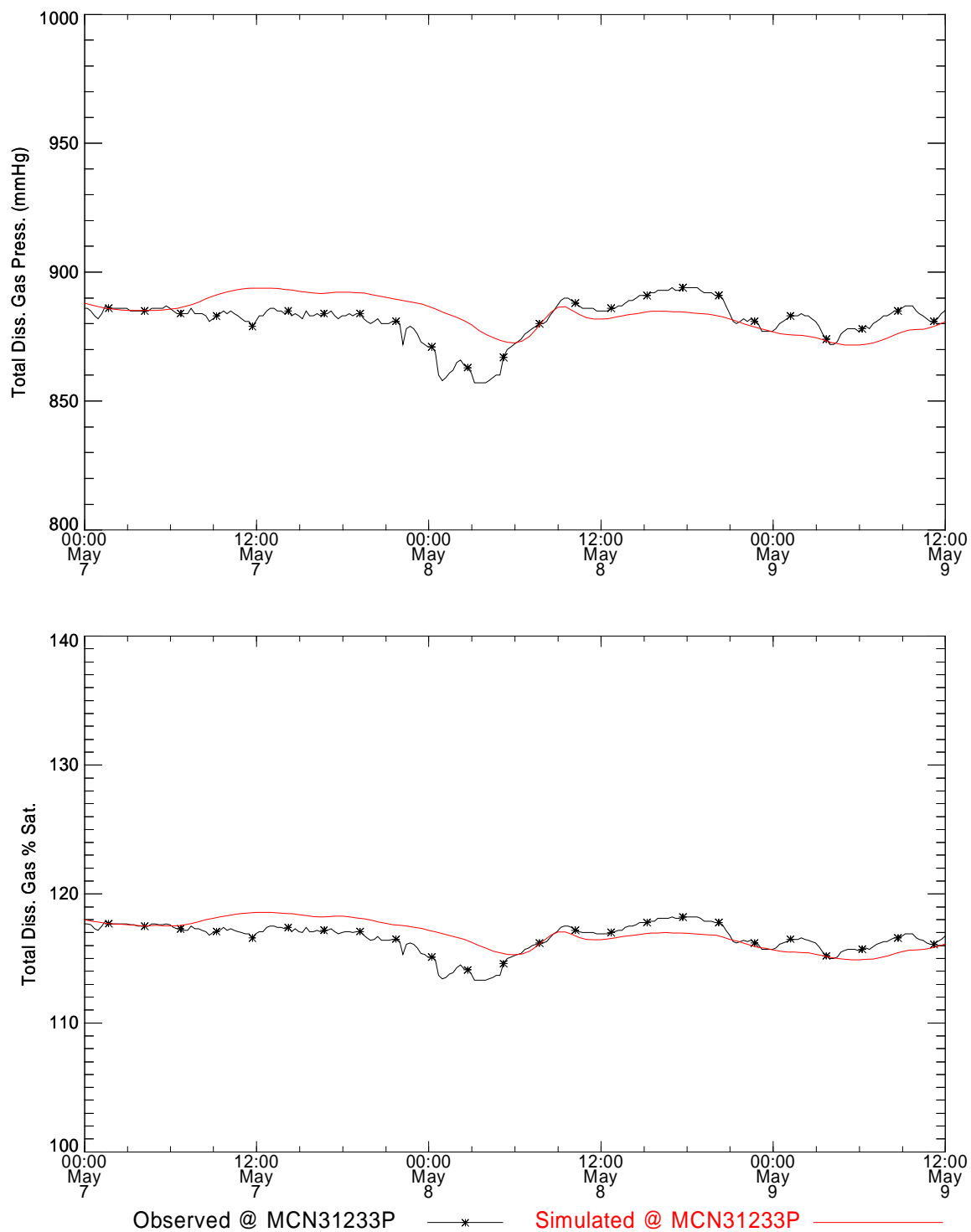
**Figure 108. Temperature and total dissolved gas time series comparisons near Columbia River Mile 314.2 for the Spring 1996 pool study.**



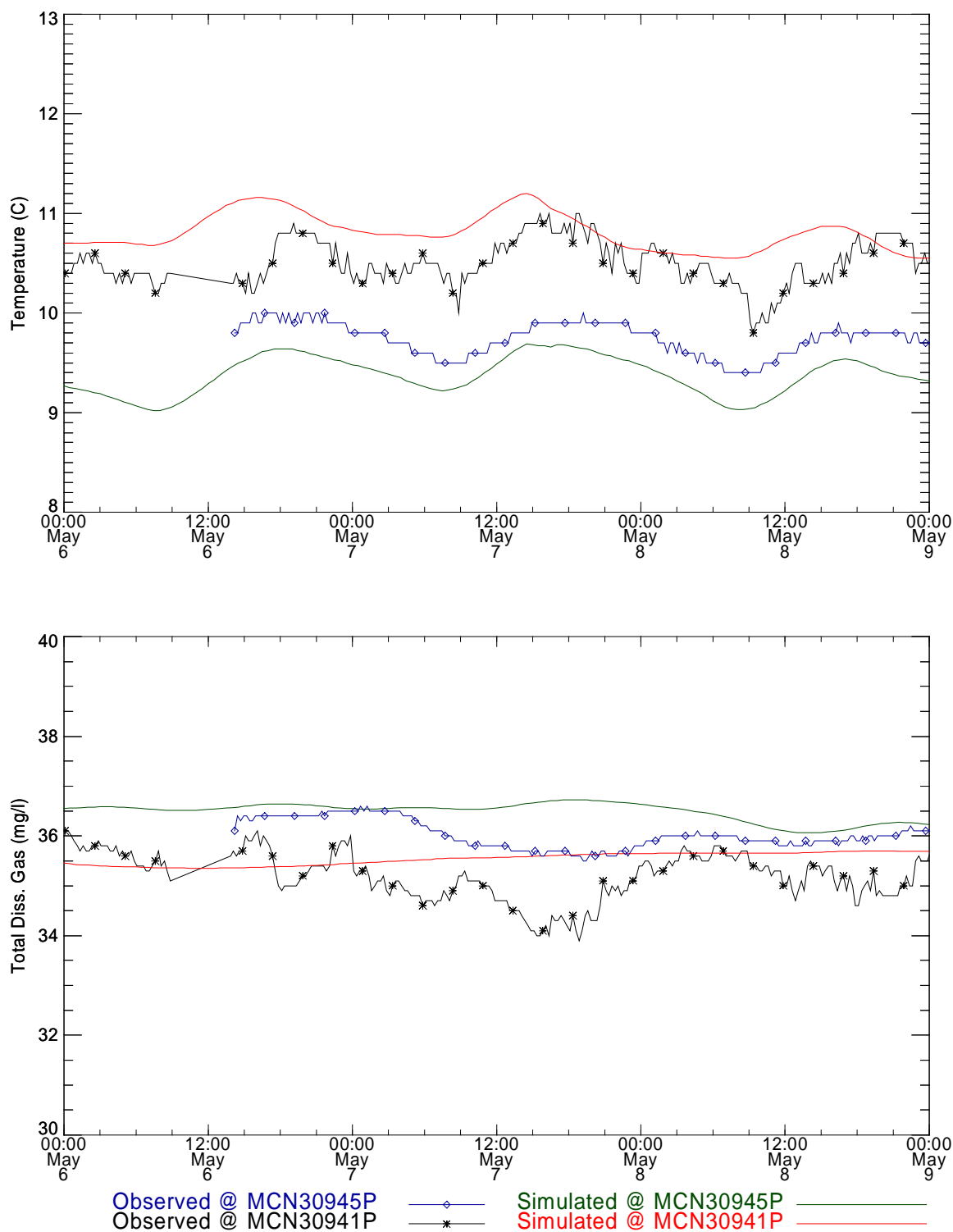
**Figure 109. Total dissolved gas time series comparisons near Columbia River Mile 314.2 for the Spring 1996 pool study.**



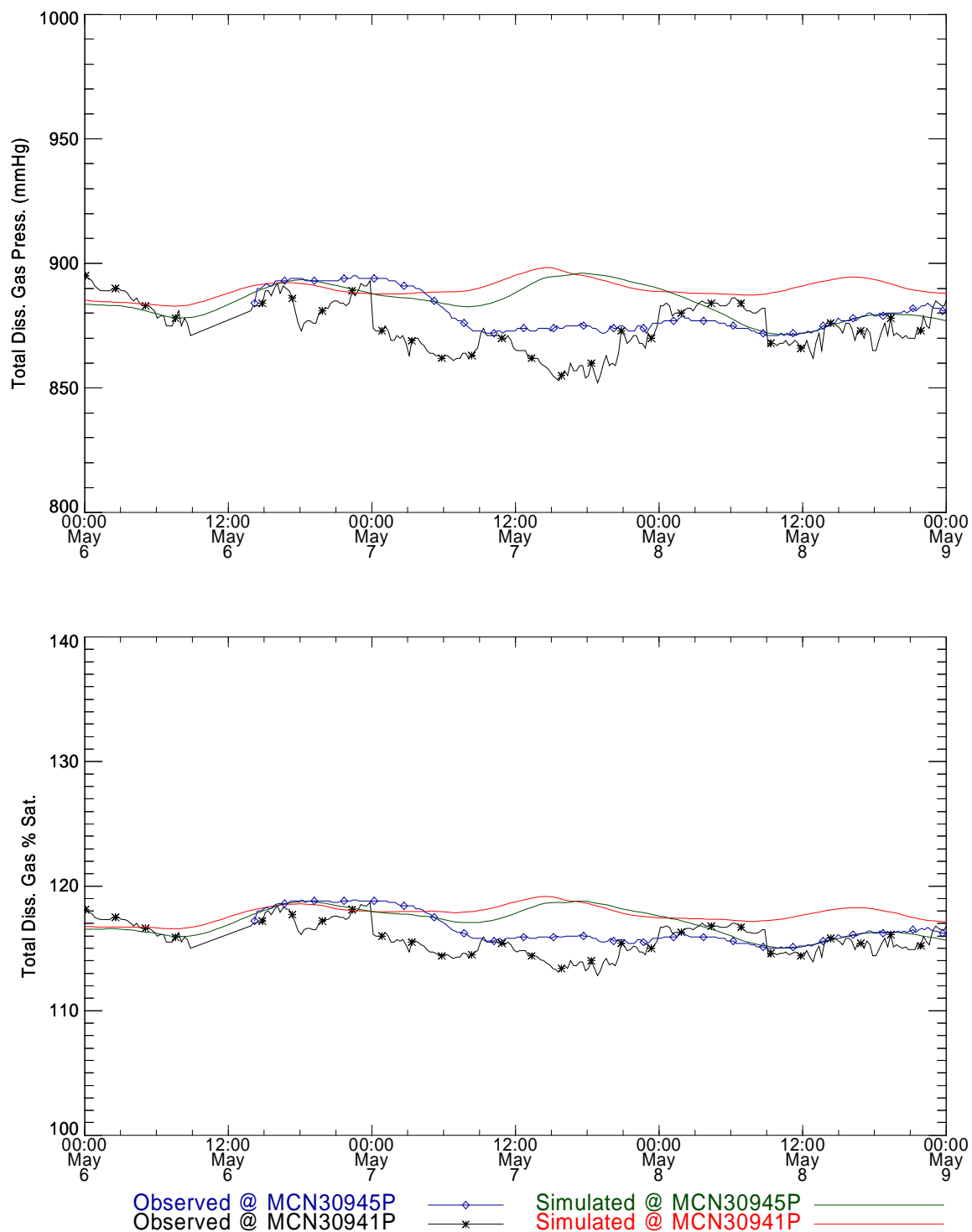
**Figure 110. Temperature and total dissolved gas time series comparisons near Columbia River Mile 312.3 for the Spring 1996 pool study.**



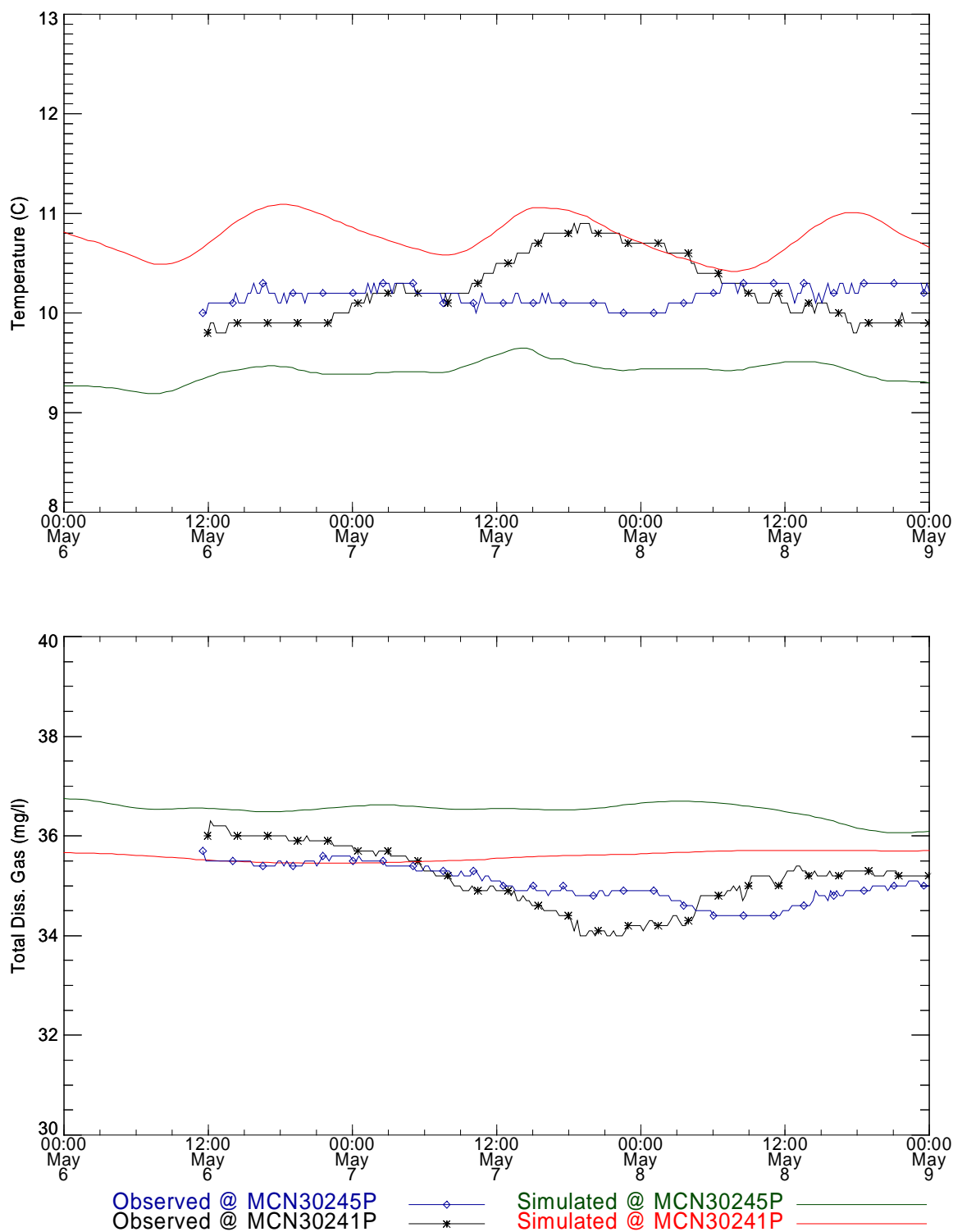
**Figure 111. Total dissolved gas time series comparisons near Columbia River Mile 312.3 for the Spring 1996 pool study.**



**Figure 112. Temperature and total dissolved gas time series comparisons near Columbia River Mile 309.4 for the Spring 1996 pool study.**

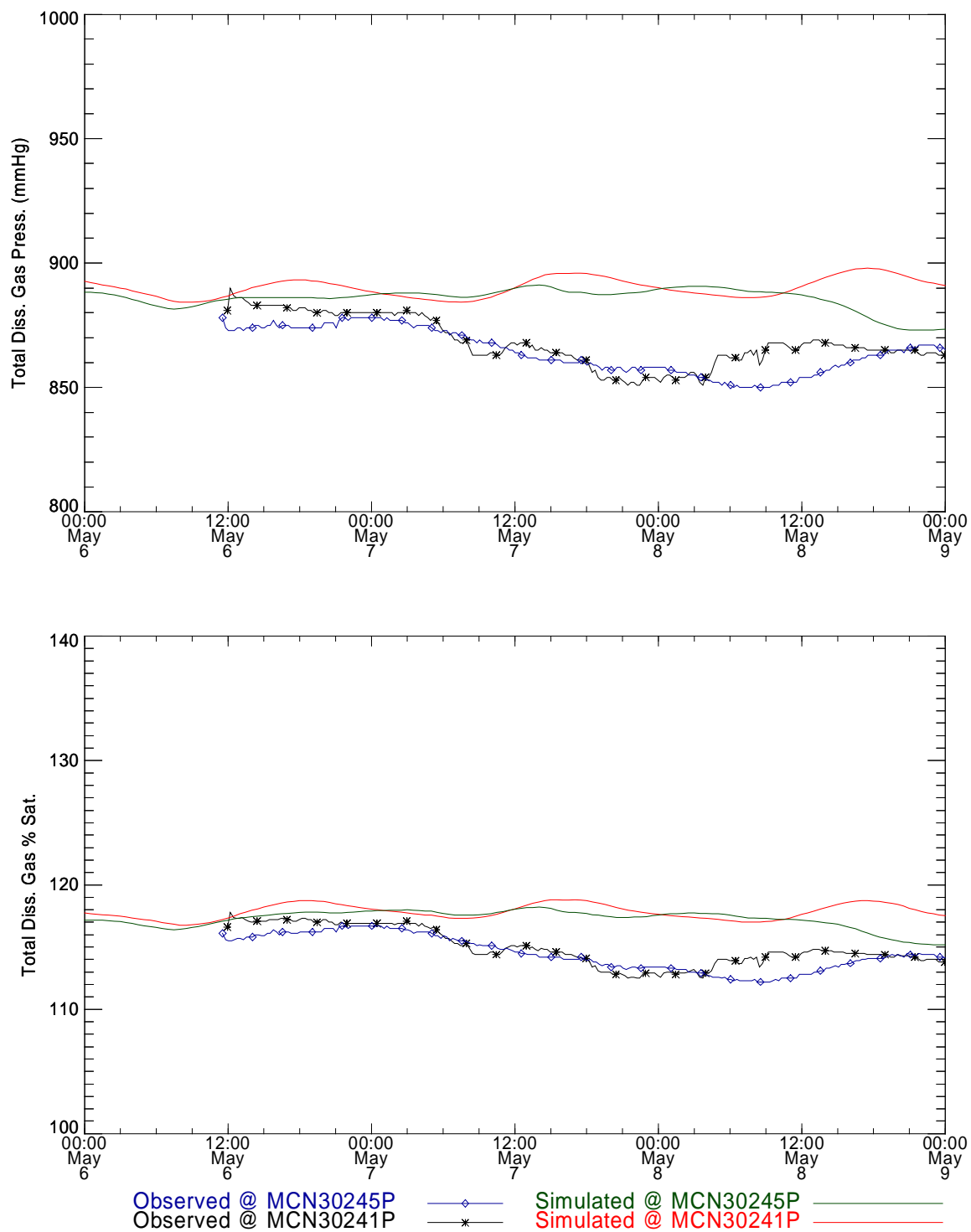


**Figure 113. Total dissolved gas time series comparisons near Columbia River Mile 309.4 for the Spring 1996 pool study.**

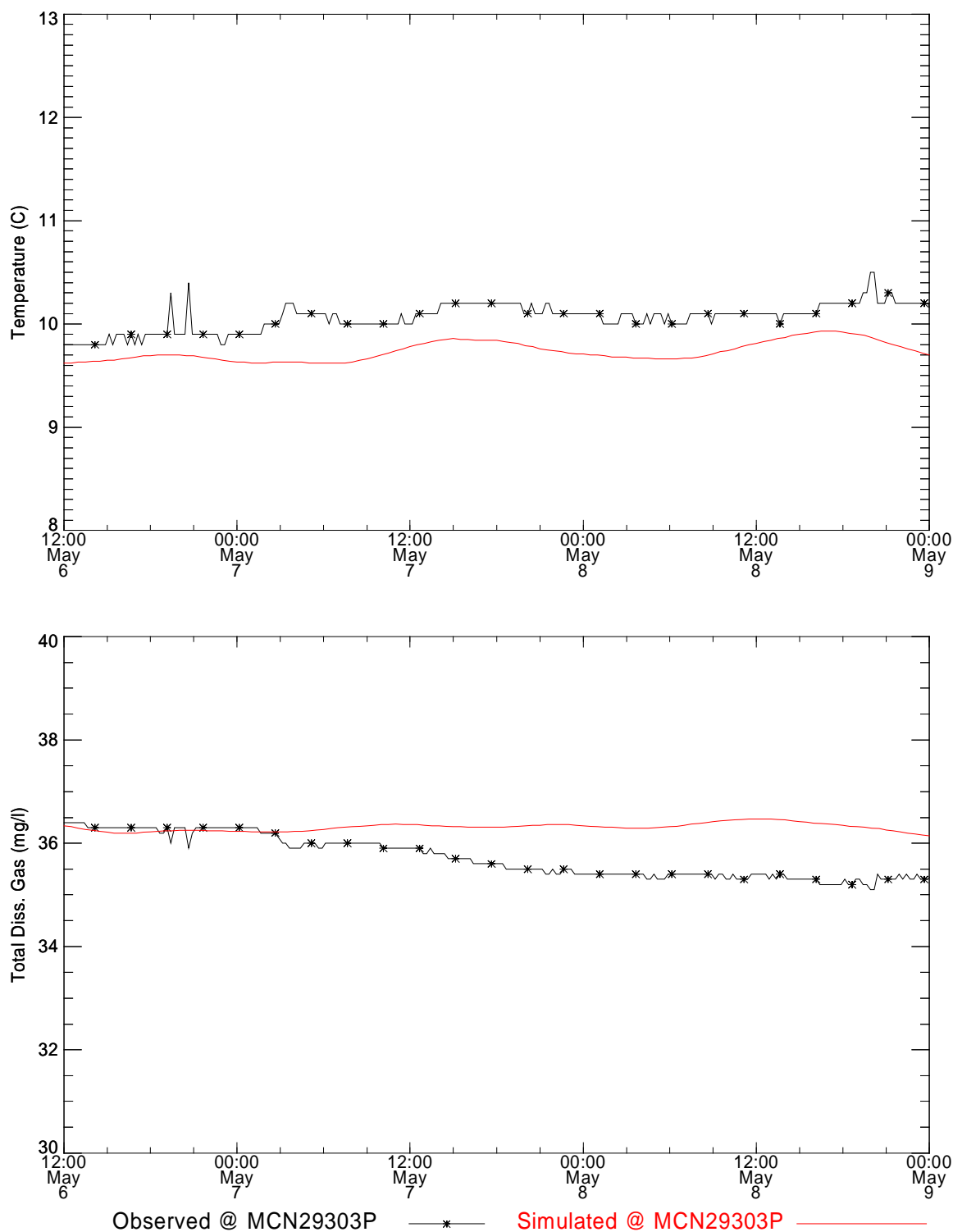


**Figure 114. Temperature and total dissolved gas time series comparisons near Columbia River Mile 302.4 for the Spring 1996 pool study.**

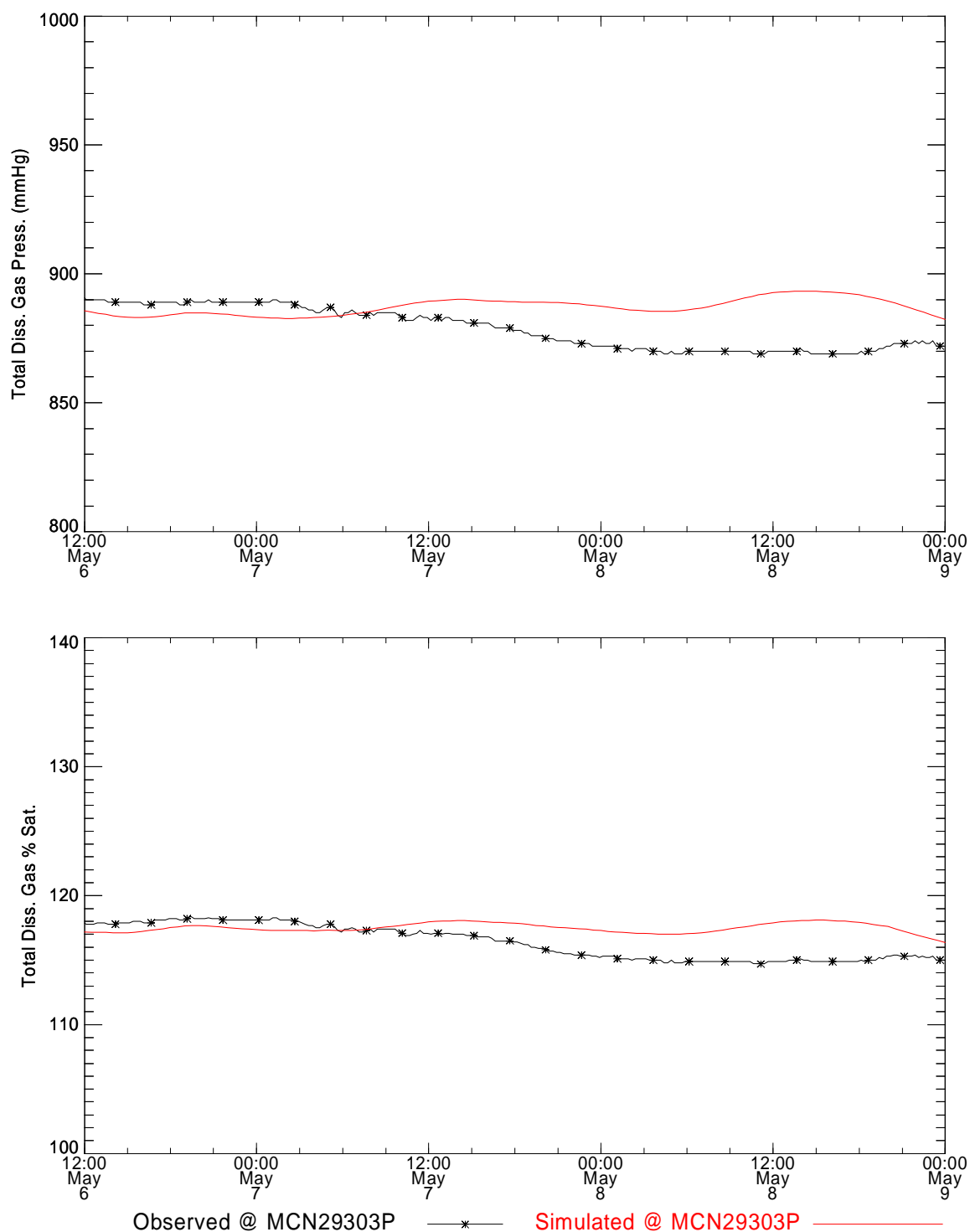




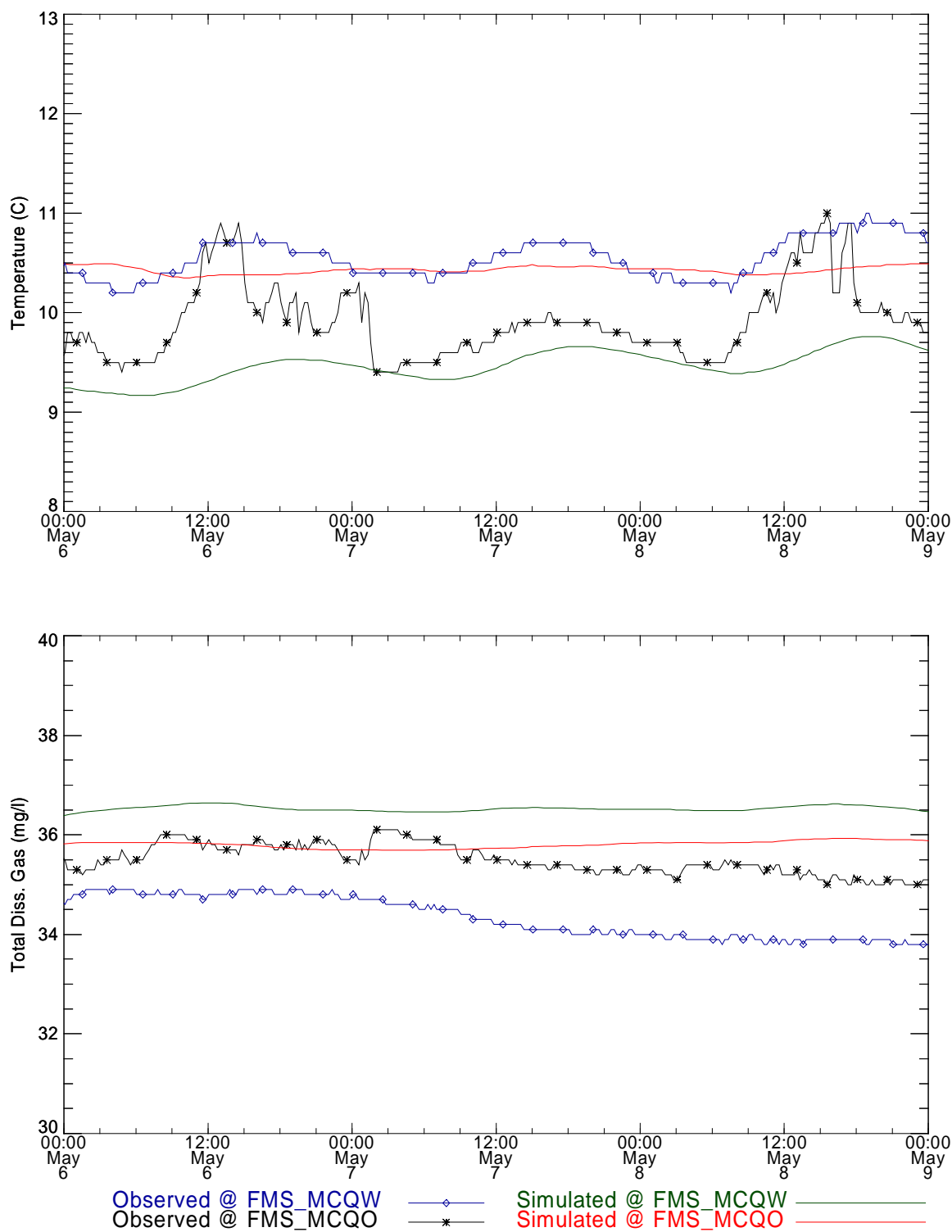
**Figure 115. Total dissolved gas time series comparisons near Columbia River Mile 302.4 for the Spring 1996 pool study.**



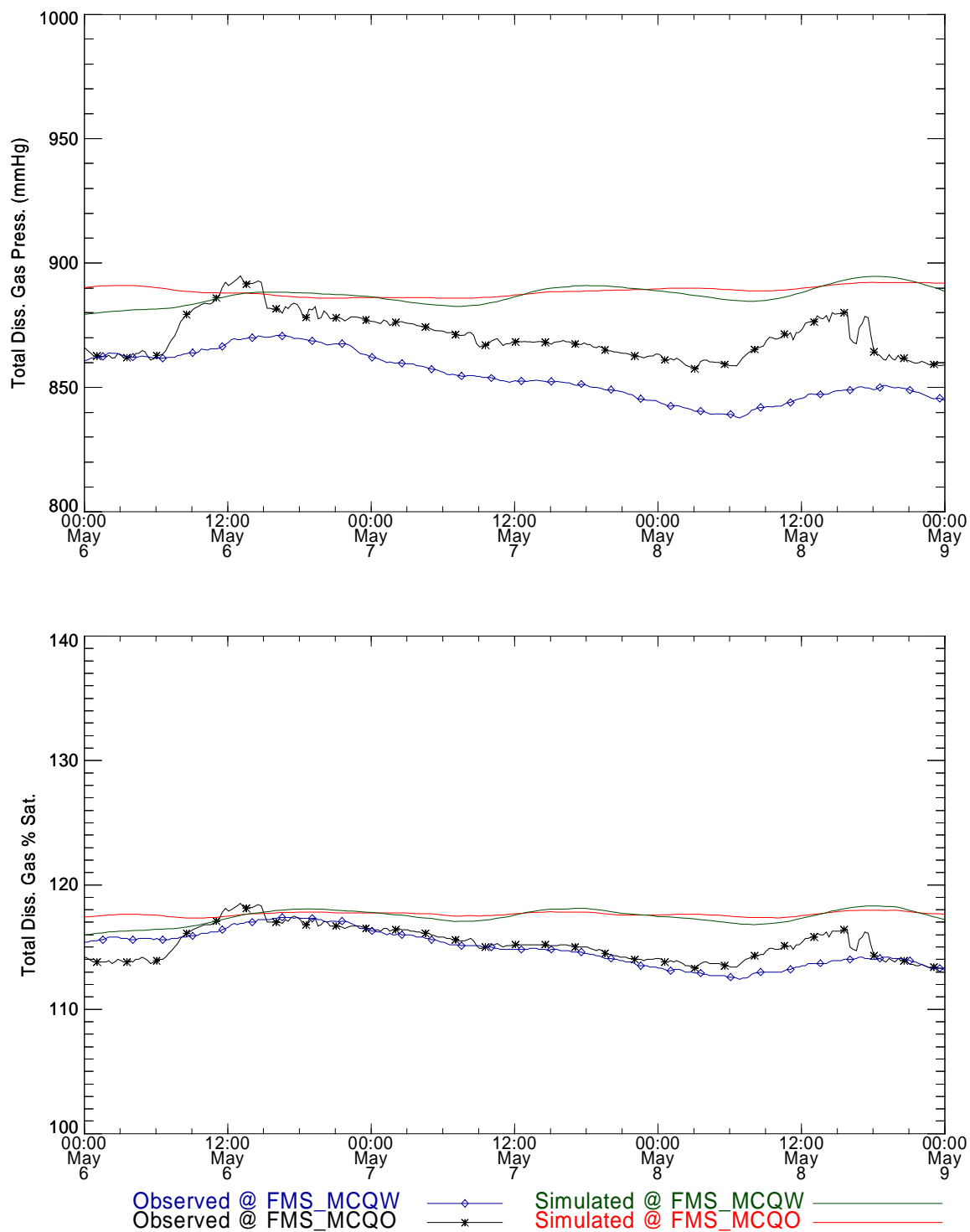
**Figure 116. Temperature and total dissolved gas time series comparisons in the McNary Dam forebay near Columbia River Mile 293 for the Spring 1996 pool study.**



**Figure 117. Total dissolved gas time series comparisons in the McNary Dam forebay near Columbia River Mile 293 for the Spring 1996 pool study.**



**Figure 118. Temperature and total dissolved gas time series comparisons at the McNary Dam Fixed Monitors for the Spring 1996 pool study.**



**Figure 119. Total dissolved gas time series comparisons at the McNary Dam Fixed Monitors for the Spring 1996 pool study.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_IDSW	11.53	11.25	0.19	0.14	0.32
Concentration (mg/l)					
FMS_IDSW	35.5	36.03	0.66	0.51	0.76
Gas Pressure (mmHg)					
FMS_IDSW	902.41	910.63	17.21	12.27	17.08
% Saturation					
FMS_IDSW	119.32	120.33	2.31	1.64	2.24

**Table 38. Statistical summary of measurements and simulations near Ice Harbor Dam for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_IDSW	100	90.54	97.97	98.31

**Table 39. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
IHRNLGWQ2P	10.99	11.30	0.07	0.08	0.32
IHRNLGWQ5P	10.99	11.30	0.08	0.08	0.32
Concentration (mg/l)					
IHRNLGWQ2P	35.25	34.64	0.43	0.51	0.7
IHRNLGWQ5P	37.04	37.00	0.81	0.84	0.18
Gas Pressure (mmHg)					
IHRNLGWQ2P	885.59	876.76	11.40	13.72	12.21
IHRNLGWQ5P	930.00	935.88	19.83	20.71	7.32
% Saturation					
IHRNLGWQ2P	117.07	115.90	1.60	1.95	1.61
IHRNLGWQ5P	122.94	123.71	2.57	2.67	0.97

**Table 40. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
IHRNLGWQ2P	100	90.89	100	100
IHRNLGWQ5P	100	99.60	100	100

**Table 41. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00895P	11.09	11.31	0.07	0.08	0.22
MCN00894P	10.98	11.31	0.07	0.08	0.33
Concentration (mg/l)					
MCN00895P	36.52	36.46	0.78	0.69	0.35
MCN00894P	34.47	34.83	0.48	0.47	0.38
Gas Pressure (mmHg)					
MCN00895P	919.33	922.41	19.02	17.33	9.31
MCN00894P	865.90	881.58	12.84	12.69	15.99
% Saturation					
MCN00895P	121.53	121.93	2.43	2.26	1.23
MCN00894P	114.47	116.54	1.83	1.81	2.11

**Table 42. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00895P	100	98.77	99.80	99.80
MCN00894P	100	98.98	100	100

**Table 43. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00612P	11.01	11.34	0.12	0.12	0.33
MCN00615P	10.98	11.33	0.08	0.07	0.36
MCN00611P	11.11	11.34	0.17	0.16	0.25
Concentration (mg/l)					
MCN00612P	35.08	35.02	0.27	0.29	0.19
MCN00615P	36.04	35.47	0.51	0.37	0.94
MCN00611P	34.88	34.89	0.33	0.29	0.21
Gas Pressure (mmHg)					
MCN00612P	881.66	886.99	8.37	8.18	6.88
MCN00615P	905.09	898.27	12.35	9.66	19.86
MCN00611P	878.56	883.81	10.51	8.43	7.46
% Saturation					
MCN00612P	116.6	117.31	1.21	1.19	0.91
MCN00615P	119.7	118.8	1.66	1.31	2.62
MCN00611P	116.19	116.88	1.47	1.24	0.99

**Table 44. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	± 5.00% Sat
MCN00612P	100	100	100	100
MCN00615P	100	69.67	94.34	94.09
MCN00611P	100	99.49	100	100

**Table 45. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**



Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00221P	11.05	11.26	0.24	0.21	0.24
MCN00223P	11.00	11.27	0.17	0.21	0.27
MCN00225P	11.00	11.27	0.18	0.23	0.29
Concentration (mg/l)					
MCN00221P	34.29	35.71	0.42	0.47	1.52
MCN00223P	34.25	35.27	0.35	0.51	1.11
MCN00225P	35.64	35.07	0.42	0.57	0.88
Gas Pressure (mmHg)					
MCN00221P	862.72	902.82	13.22	10.77	42.45
MCN00223P	860.83	891.99	10.60	12.03	32.64
MCN00225P	895.32	887.02	10.82	13.6	18.51
% Saturation					
MCN00221P	114.00	119.29	1.88	1.46	5.61
MCN00223P	113.74	117.86	1.52	1.67	4.31
MCN00225P	118.30	117.21	1.38	1.88	2.44

**Table 46. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	± 5.00% Sat
MCN00221P	100	30.41	44.26	44.26
MCN00223P	100	70.61	82.43	82.43
MCN00225P	100	75	95.61	95.27

**Table 47. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32613P	9.07	9.08	0.25	0.24	0.05
Concentration (mg/l)					
MCN32613P	36.39	36.39	0.29	0.29	0.03
Gas Pressure (mmHg)					
MCN32613P	875.54	876.00	9.62	9.55	1.11
% Saturation					
MCN32613P	115.69	115.75	1.42	1.41	0.15

**Table 48. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32613P	100	100	100	100

**Table 49. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32355P	9.31	9.24	0.20	0.12	0.21
MCN32354P	9.25	9.22	0.16	0.13	0.06
MCN32352P	10.13	10.62	0.32	0.32	0.57
MCN32351P	11.15	11.43	0.30	0.34	0.41
Concentration (mg/l)					
MCN32355P	36.99	36.40	0.27	0.24	0.67
MCN32354P	37.13	36.39	0.24	0.24	0.74
MCN32352P	36.39	35.80	0.30	0.23	0.65
MCN32351P	34.55	35.24	0.49	0.26	0.80
Gas Pressure (mmHg)					
MCN32355P	894.52	879.48	7.56	7.09	18.09
MCN32354P	896.36	879.01	7.07	7.05	17.41
MCN32352P	896.34	892.27	7.74	6.85	7.62
MCN32351P	871.16	894.56	15.02	10.08	25.42
% Saturation					
MCN32355P	118.21	116.28	1.16	1.09	2.37
MCN32354P	118.52	116.22	1.08	1.08	2.31
MCN32352P	118.53	117.97	1.04	0.97	1.03
MCN32351P	115.12	118.27	1.92	1.35	3.42

**Table 50. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32355P	100	89.44	97.10	97.10
MCN32354P	100	100	100	100
MCN32352P	97.52	94.41	100	100
MCN32351P	97.52	74.95	90.89	89.03

**Table 51. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN31422P	10.91	10.41	0.38	0.26	0.54
Concentration (mg/l)					
MCN31422P	35.04	35.82	0.64	0.09	1.03
Gas Pressure (mmHg)					
MCN31422P	878.71	888.70	16.36	5.21	19.51
% Saturation					
MCN31422P	116.14	117.52	2.11	0.88	2.60

**Table 52. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN31422P	98.97	69.51	92.76	92.76

**Table 53. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN31233P	10.23	9.96	0.33	0.17	0.40
Concentration (mg/l)					
MCN31233P	35.84	36.00	0.37	0.13	0.40
Gas Pressure (mmHg)					
MCN31233P	885.27	884.28	8.46	5.38	8.39
% Saturation					
MCN31233P	117.01	116.94	1.18	0.95	1.08

**Table 54. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN31233P	100	95.87	99.74	99.74

**Table 55. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN30945P	9.74	9.46	0.18	0.21	0.31
MCN30941P	10.48	10.82	0.21	0.18	0.40
Concentration (mg/l)					
MCN30945P	36.06	36.31	0.26	0.26	0.45
MCN30941P	35.33	35.61	0.46	0.09	0.54
Gas Pressure (mmHg)					
MCN30945P	881.13	881.58	7.21	7.73	9.04
MCN30941P	877.65	891.48	9.58	3.04	17.38
% Saturation					
MCN30945P	116.47	116.59	1.10	1.28	1.18
MCN30941P	116.01	117.90	1.13	0.51	2.33

**Table 56. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN30945P	100	93.11	100	100
MCN30941P	100	92.09	96.17	95.92

**Table 57. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN30241P	10.18	10.8	0.28	0.22	0.72
MCN30245P	10.18	9.44	0.09	0.09	0.75
Concentration (mg/l)					
MCN30241P	35.24	35.63	0.51	0.09	0.67
MCN30245P	35.16	36.32	0.36	0.27	1.28
Gas Pressure (mmHg)					
MCN30241P	869.54	891.78	8.25	4.37	23.93
MCN30245P	867.57	881.55	8.58	6.68	19.19
% Saturation					
MCN30241P	114.94	117.94	1.21	0.62	3.23
MCN30245P	114.68	116.59	1.19	1.11	2.53

**Table 58. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN30241P	76.88	86.68	95.48	95.48
MCN30245P	100	31.91	95.23	94.72

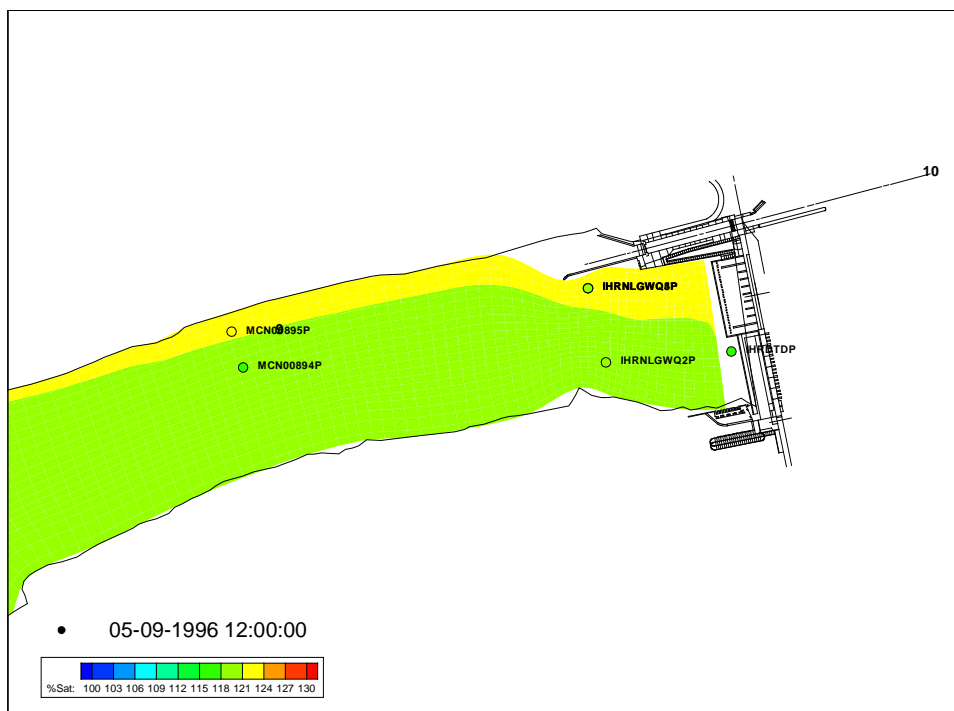
**Table 59. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_MCQW	10.40	11.85	0.32	5.26	5.66
FMS_MCQO	9.77	13.16	0.50	5.01	6.22
Concentration (mg/l)					
FMS_MCQW	34.38	34.48	0.38	4.00	4.23
FMS_MCQO	35.61	33.66	0.40	3.89	4.64
Gas Pressure (mmHg)					
FMS_MCQW	852.72	872.39	8.38	22.53	31.20
FMS_MCQO	870.54	876.76	9.79	23.97	29.72
% Saturation					
FMS_MCQW	114.43	115.28	1.27	3.11	3.31
FMS_MCQO	115.03	115.85	1.38	3.28	3.92

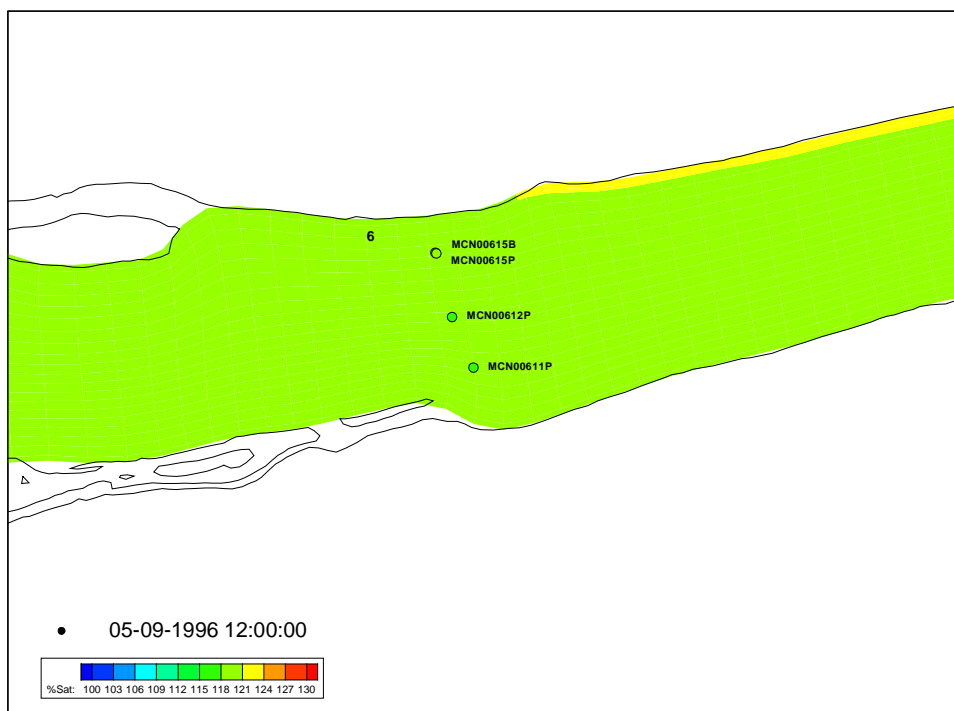
**Table 60. Statistical summary of measurements and simulations for the Spring 1996 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_MCQW	22.64	3.38	72.30	86.49
FMS_MCQO	65.20	72.30	84.80	84.80

**Table 61. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

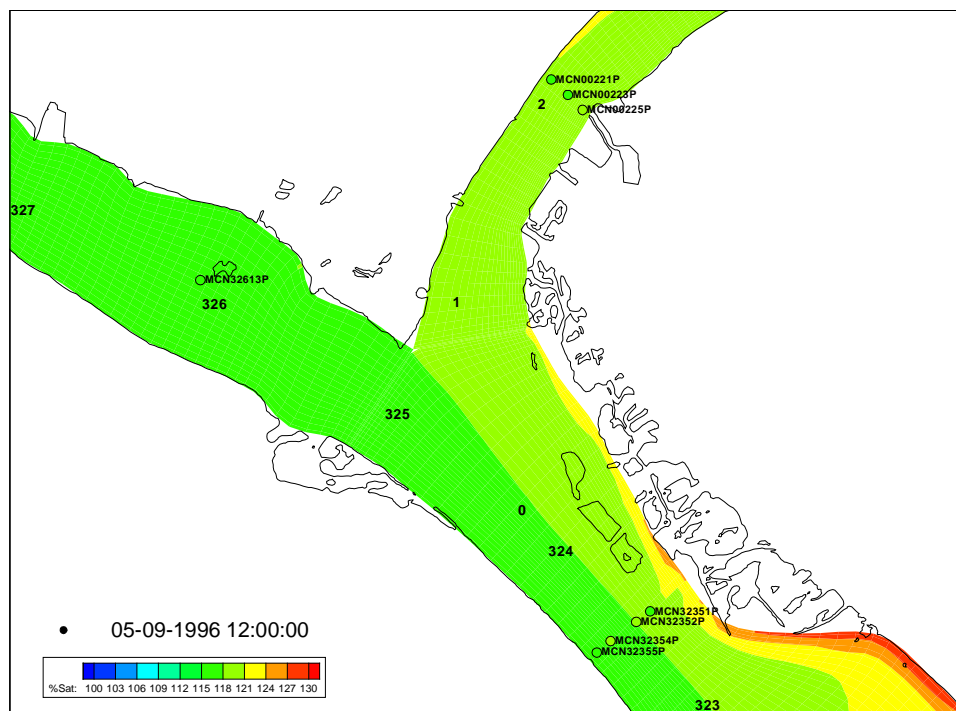


**Figure 120. Total dissolved gas simulated distribution near Ice Harbor Dam on 5-9-1996. The monitors are color coded to their measured concentration.**

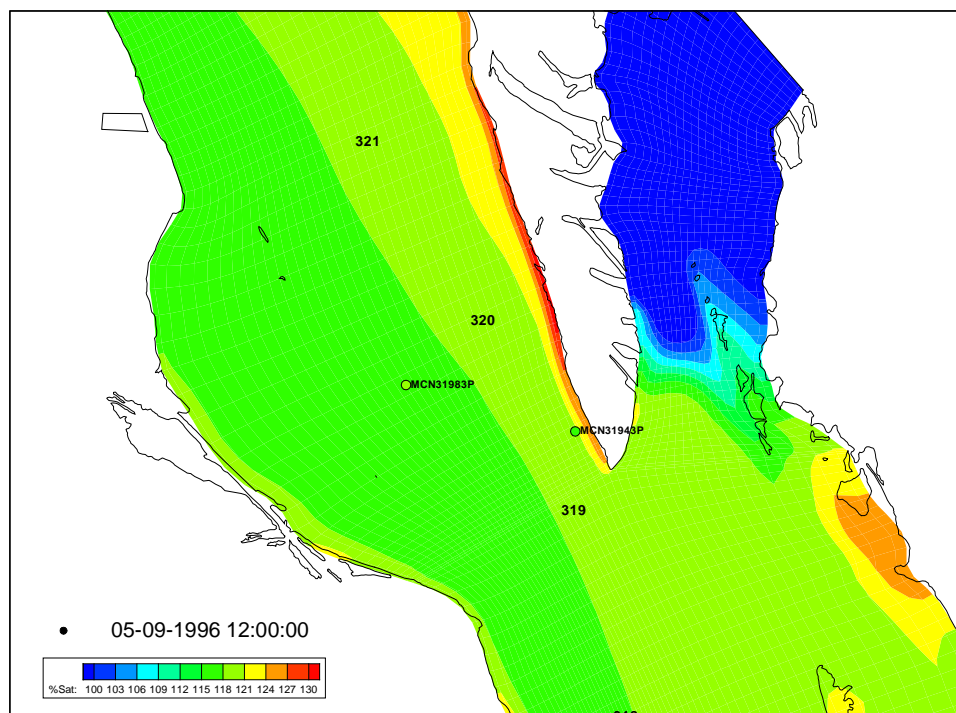


**Figure 121. Total dissolved gas simulated distribution near Snake River Mile 6.1 on 5-9-1996. The monitors are color coded to their measured concentration.**

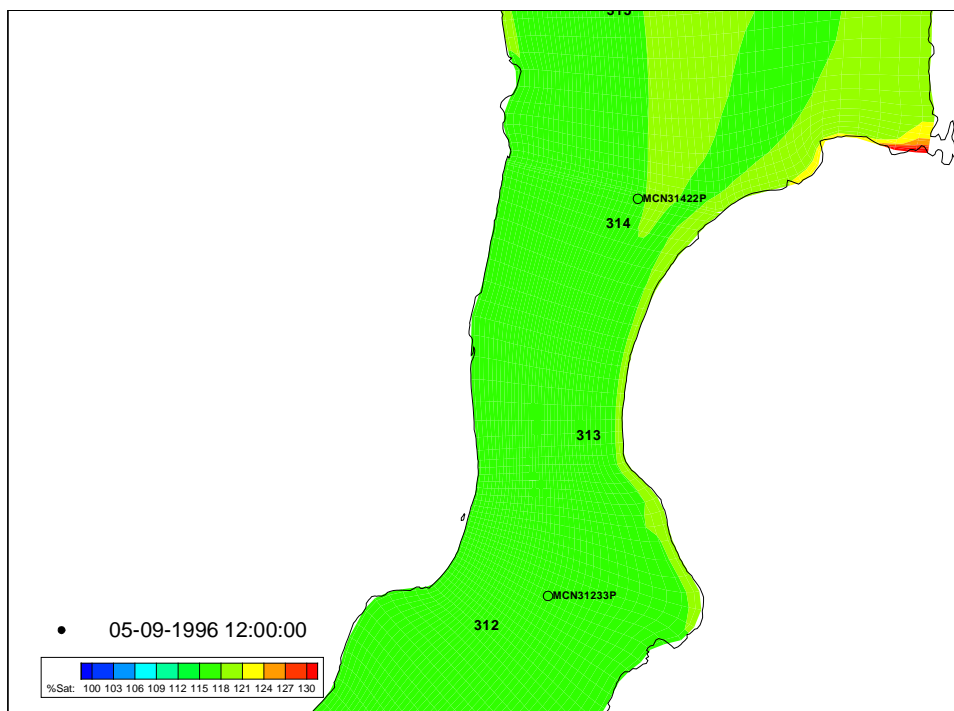




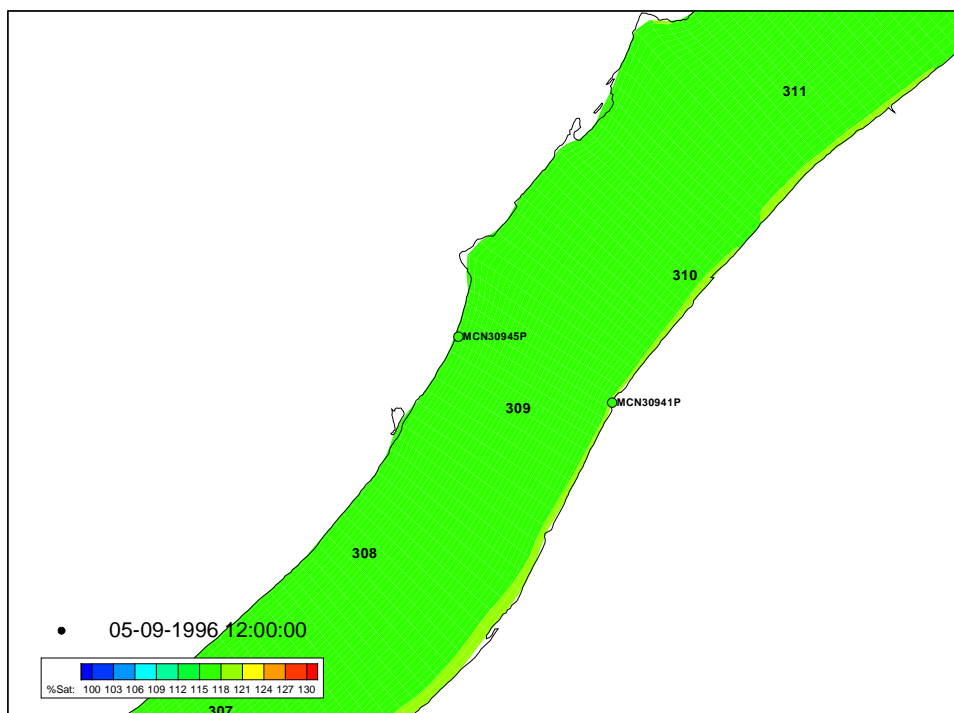
**Figure 122. Total dissolved gas simulated distribution at the confluence of the Columbia and Snake Rivers on 5-9-1996. The monitors are color coded to their measured concentration.**



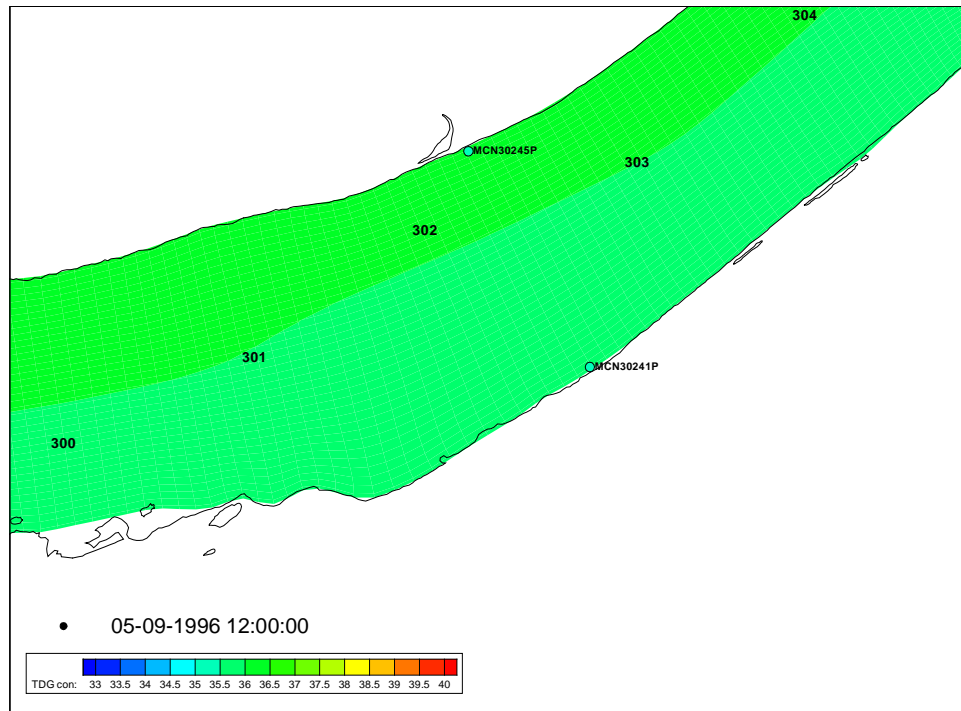
**Figure 123. Total dissolved gas simulated distribution near Columbia River Mile 320 on 5-9-1996. The monitors are color coded to their measured concentration.**



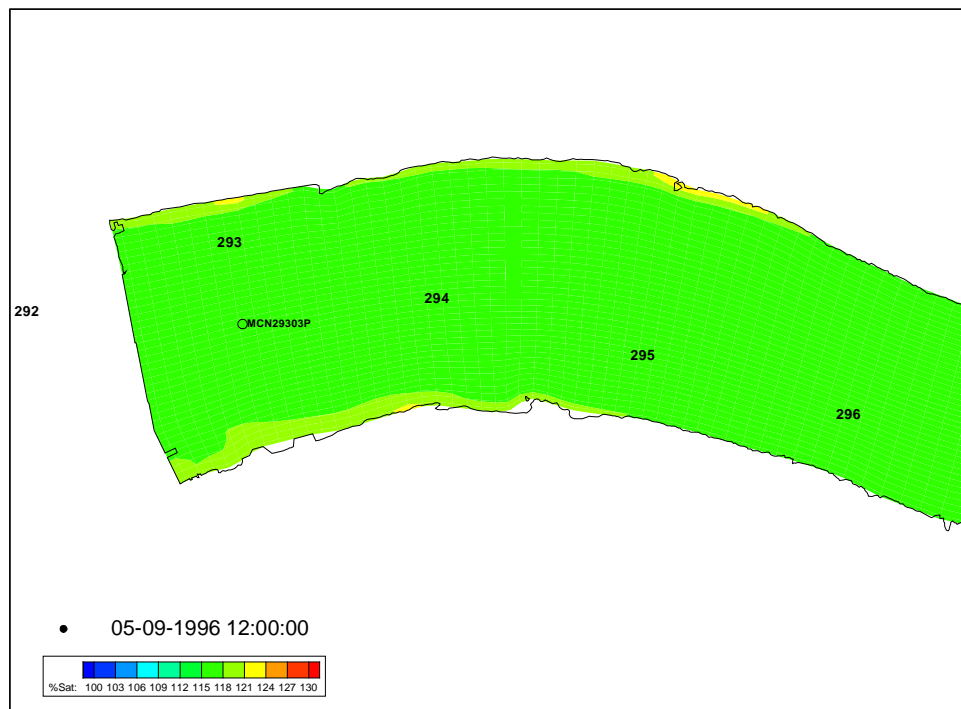
**Figure 124. Total dissolved gas simulated distribution at Wallula Gap near Columbia River Mile 313 on 5-9-1996. The monitors are color coded to their measured concentration.**



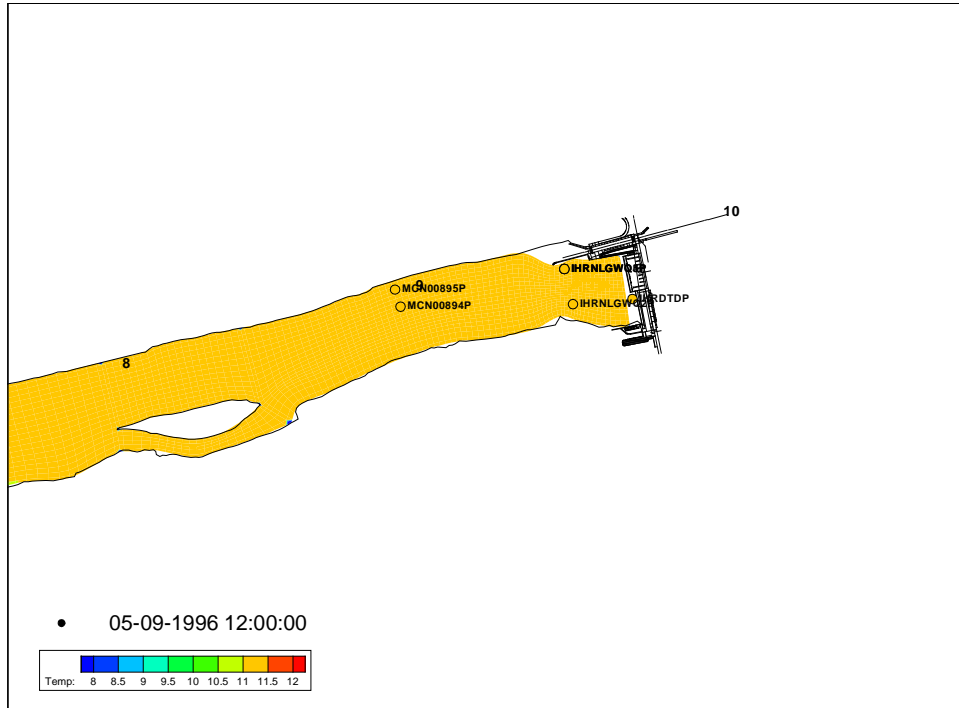
**Figure 125. Total dissolved gas simulated distribution near Columbia River Mile 309 on 5-9-1996. The monitors are color coded to their measured concentration.**



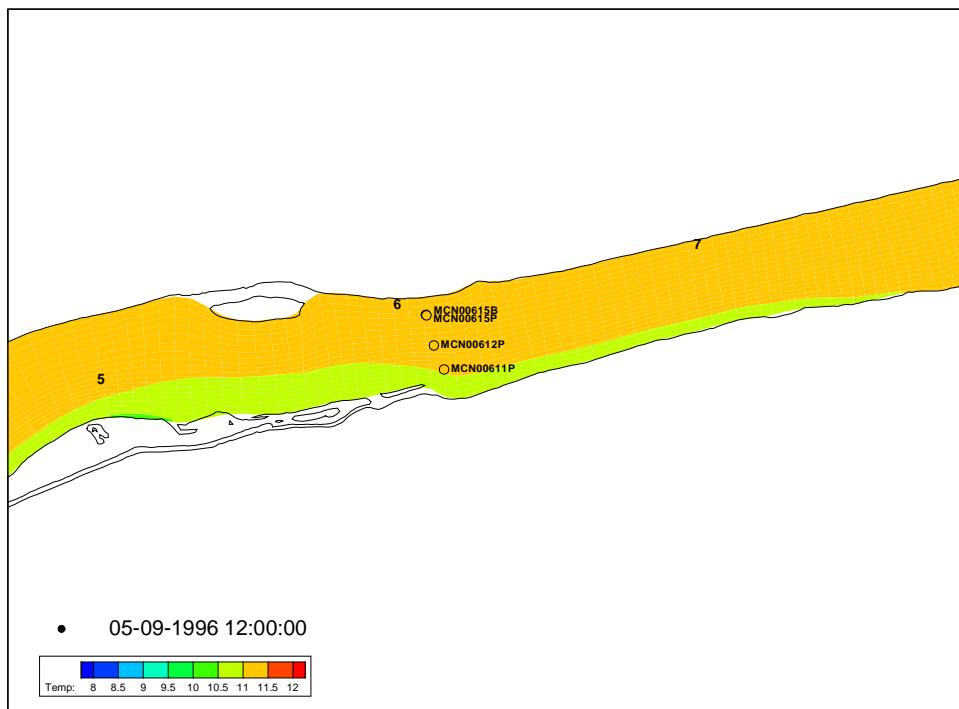
**Figure 126. Total dissolved gas simulated distribution near Columbia River Mile 302 on 5-9-1996. The monitors are color coded to their measured concentration.**



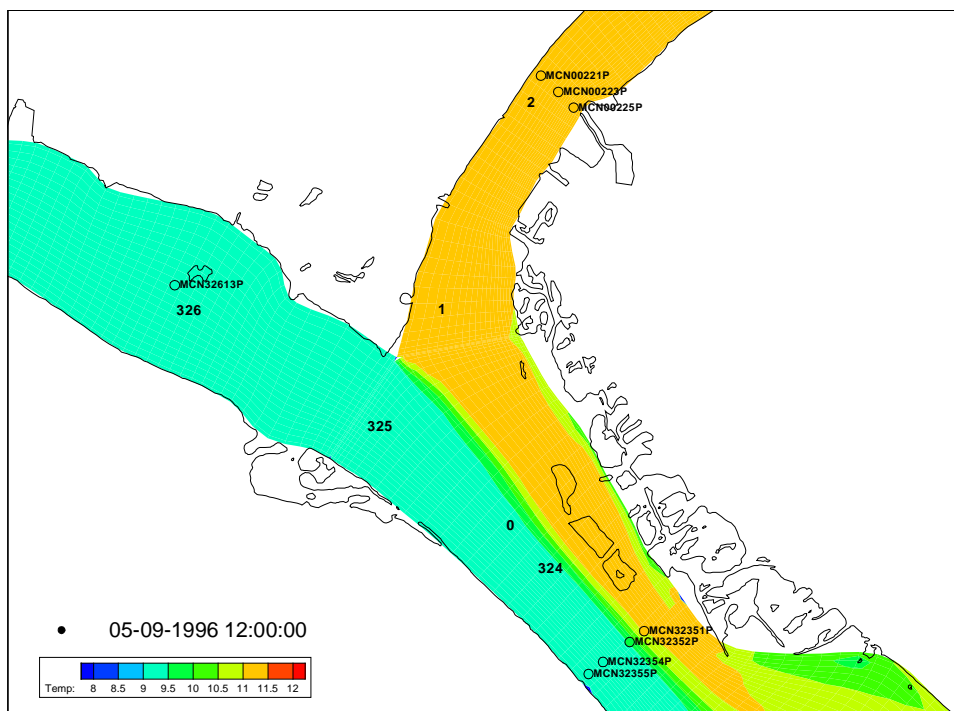
**Figure 127. Total dissolved gas simulated distribution in the McNary Dam forebay near Columbia River Mile 293 on 5-9-1996. The monitors are color coded to their measured concentration.**



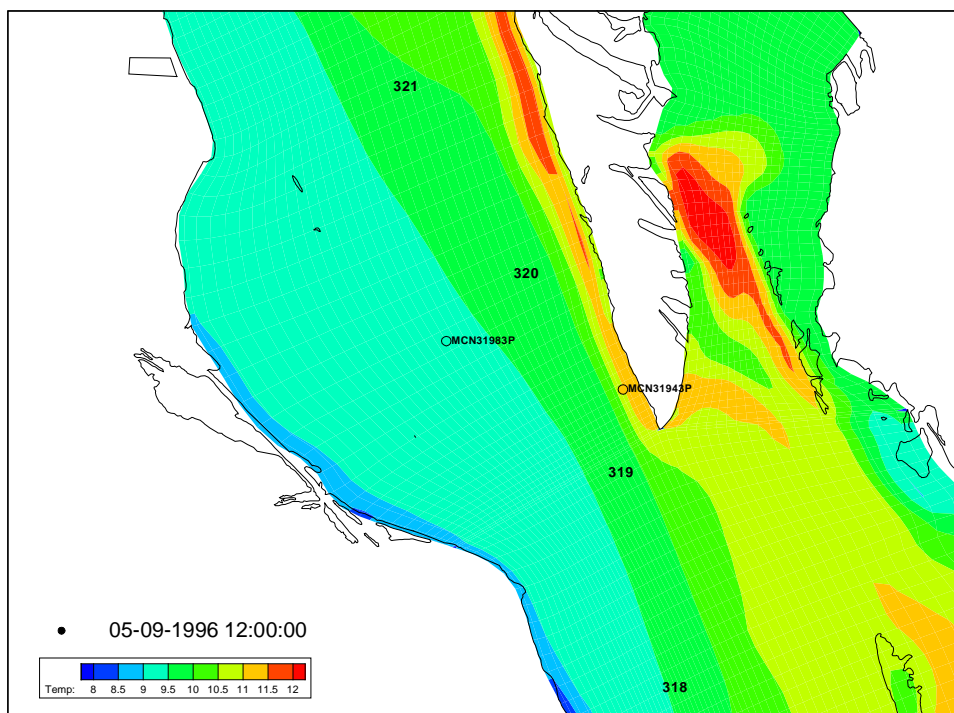
**Figure 128. Simulated temperature distribution near Ice Harbor Dam on 5-9-1996. The monitors are color coded to their measured temperature.**



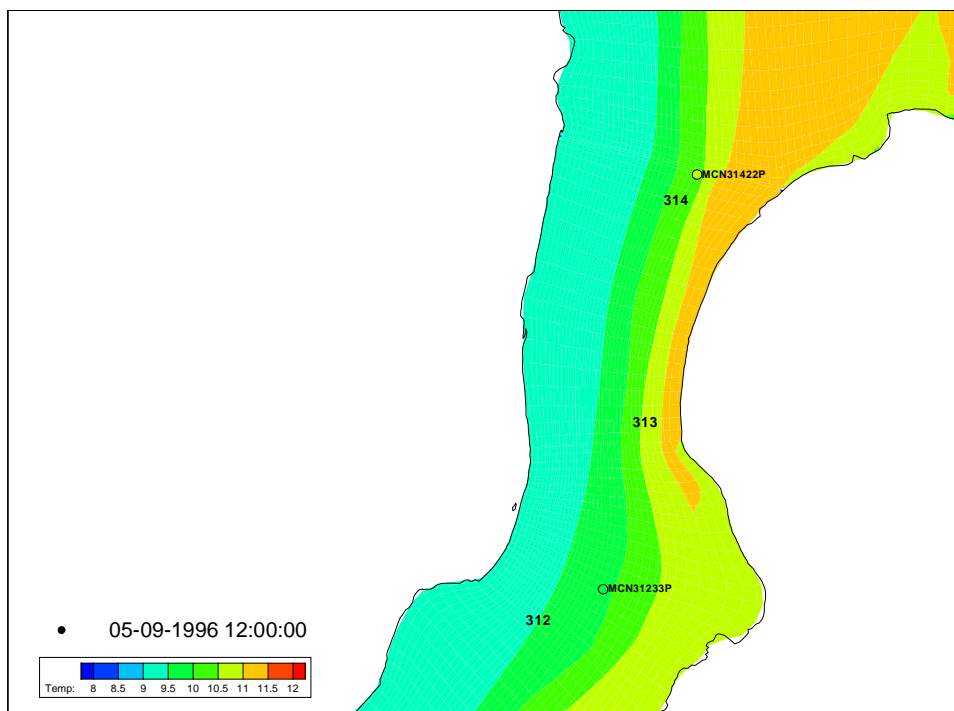
**Figure 129. Simulated temperature distribution near Snake River Mile 6.1 on 5-9-1996. The monitors are color coded to their measured temperature.**



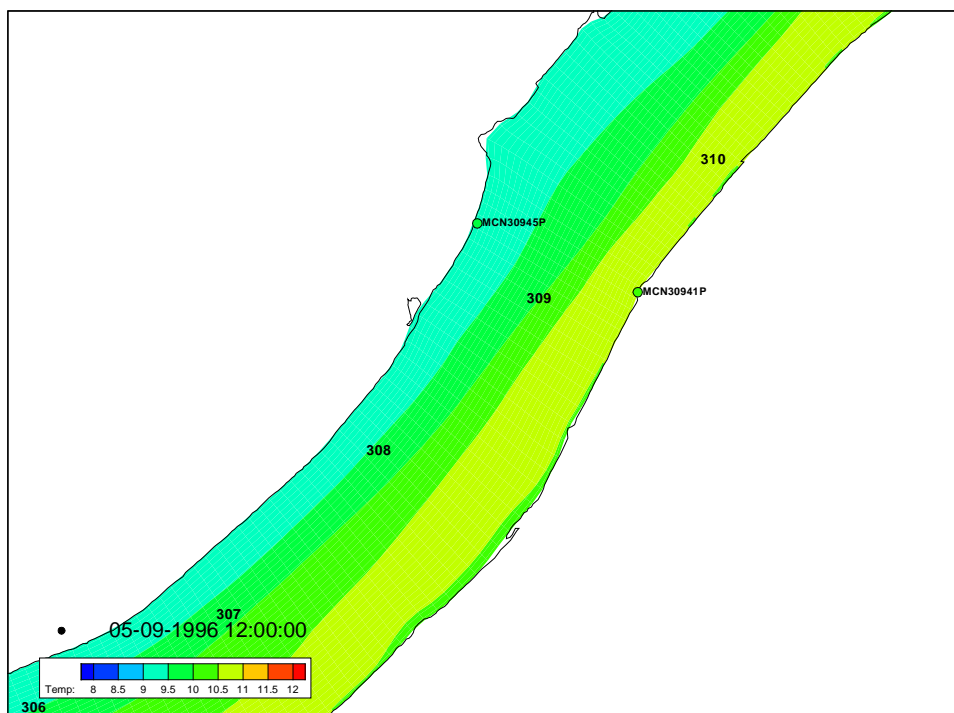
**Figure 130. Simulated temperature distribution at the confluence of the Columbia and Snake Rivers on 5-9-1996. The monitors are color coded to their measured temperature.**



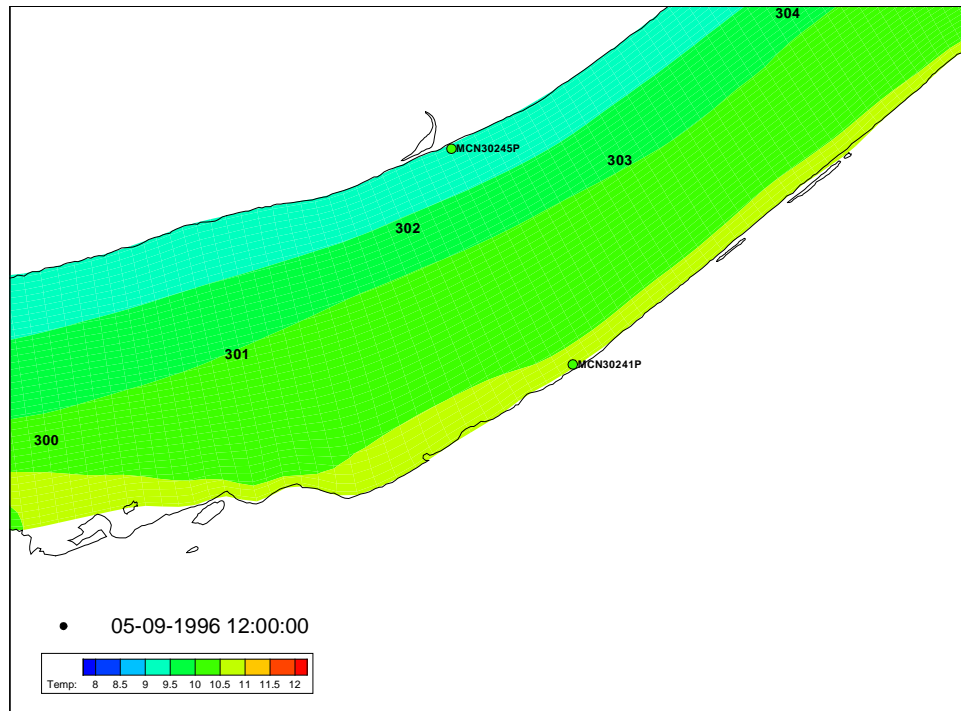
**Figure 131. Simulated temperature distribution near Columbia River Mile 320 on 5-9-1996. The monitors are color coded to their measured temperature.**



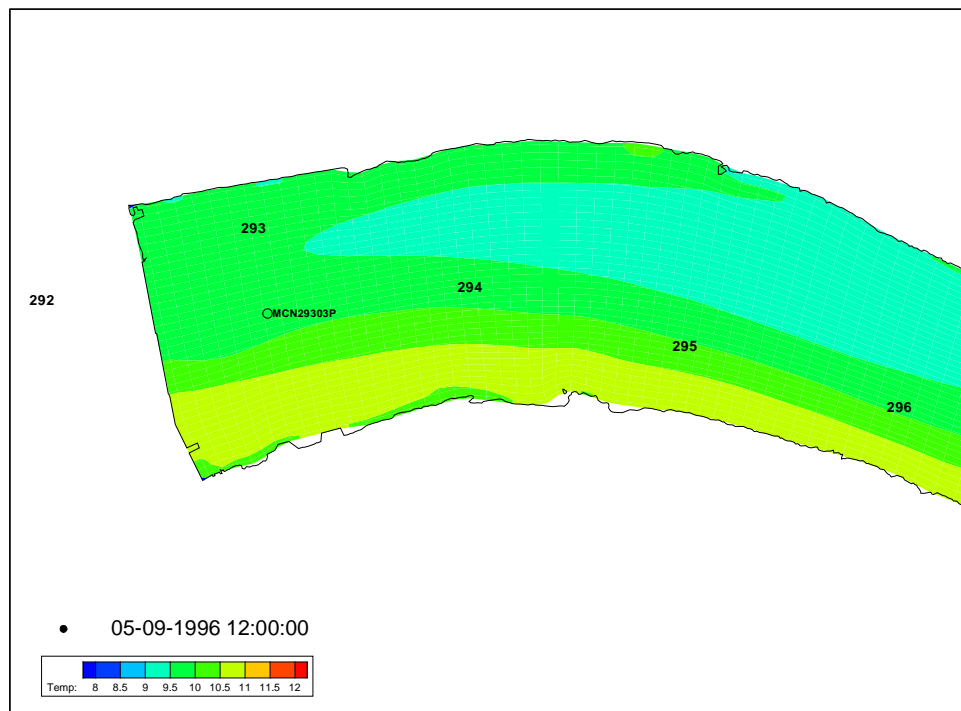
**Figure 132. Simulated temperature distribution at Wallula Gap near Columbia River Mile 313 on 5-9-1996. The monitors are color coded to their measured temperature.**



**Figure 133. Simulated temperature distribution near Columbia River Mile 309 on 5-9-1996. The monitors are color coded to their measured temperature.**



**Figure 134. Simulated temperature distribution near Columbia River Mile 302 on 5-9-1996. The monitors are color coded to their measured temperature.**



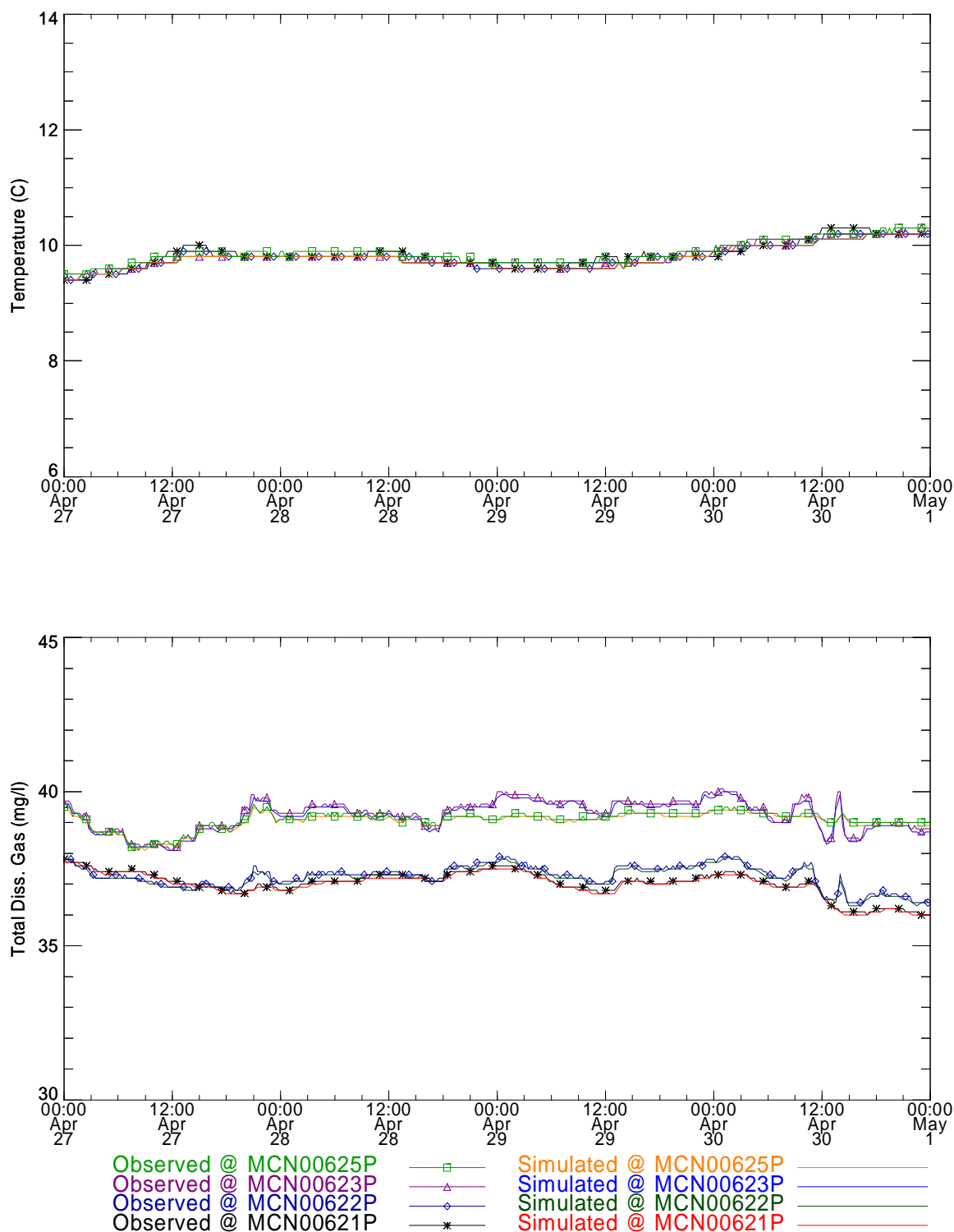
**Figure 135. Simulated temperature distribution in the McNary Dam forebay near Columbia River Mile 293 on 5-9-1996. The monitors are color coded to their measured temperature.**



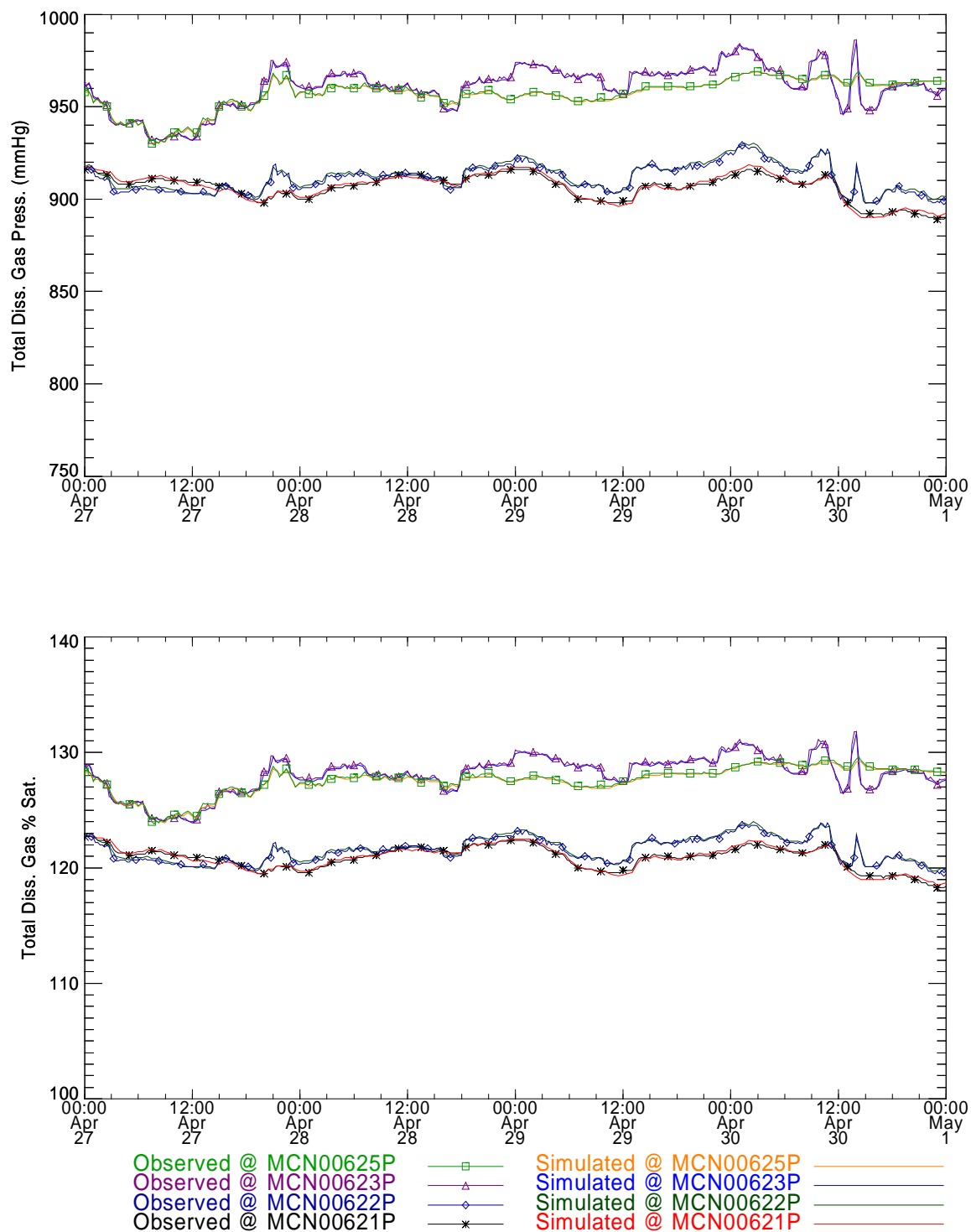
### ***1.4.3 1997 Spring Simulation***

Additional model verification will be done using the Spring 1997 pool study data. The model was configured to use boundary conditions developed from the temporary field study monitors located at Snake River Mile 6.1 instead of information at Ice Harbor Dam. The hydrodynamics were simulated using hourly spillway and powerhouse discharges at Ice Harbor Dam. The results of these simulations are shown in Figure 136 through Figure 150.

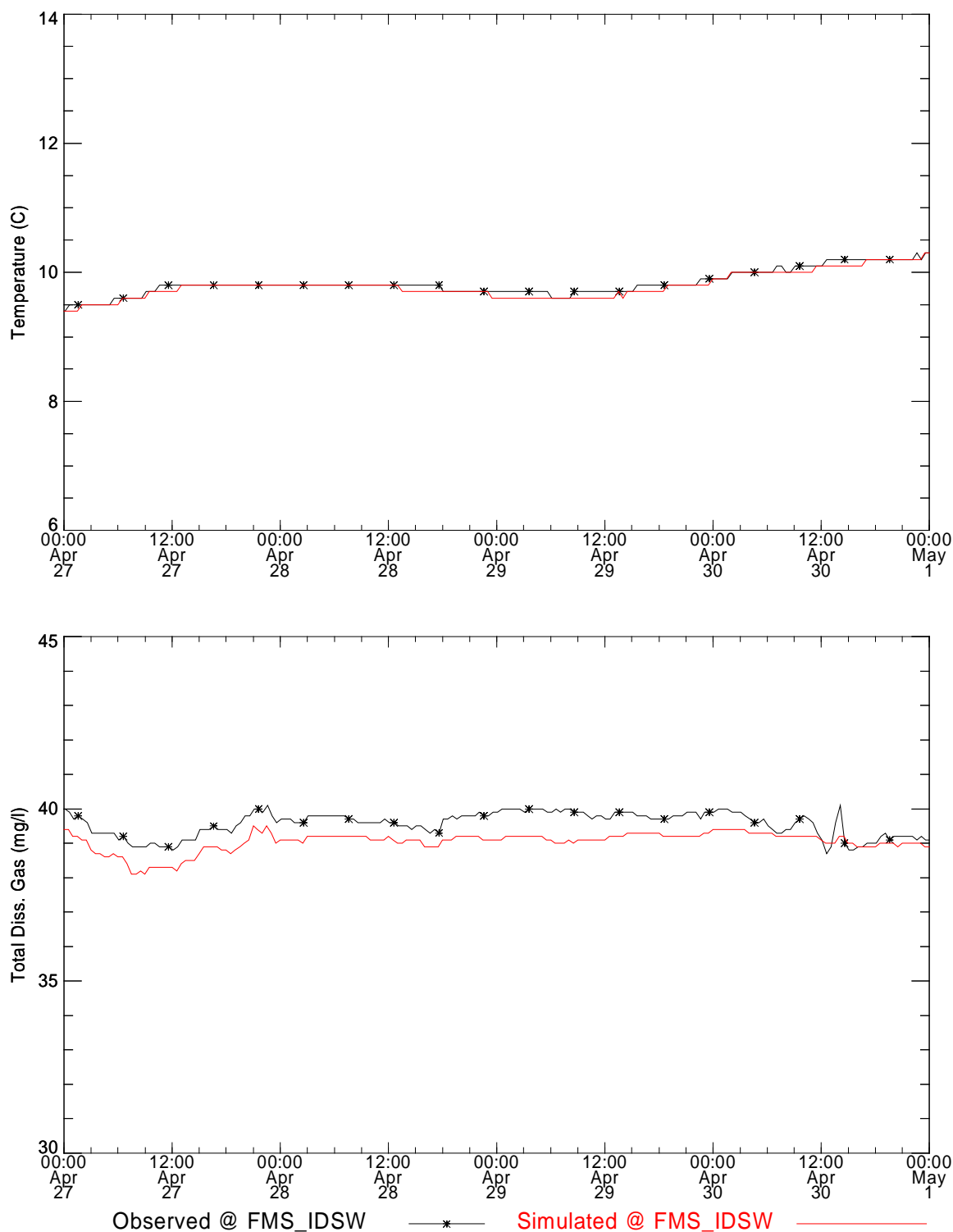




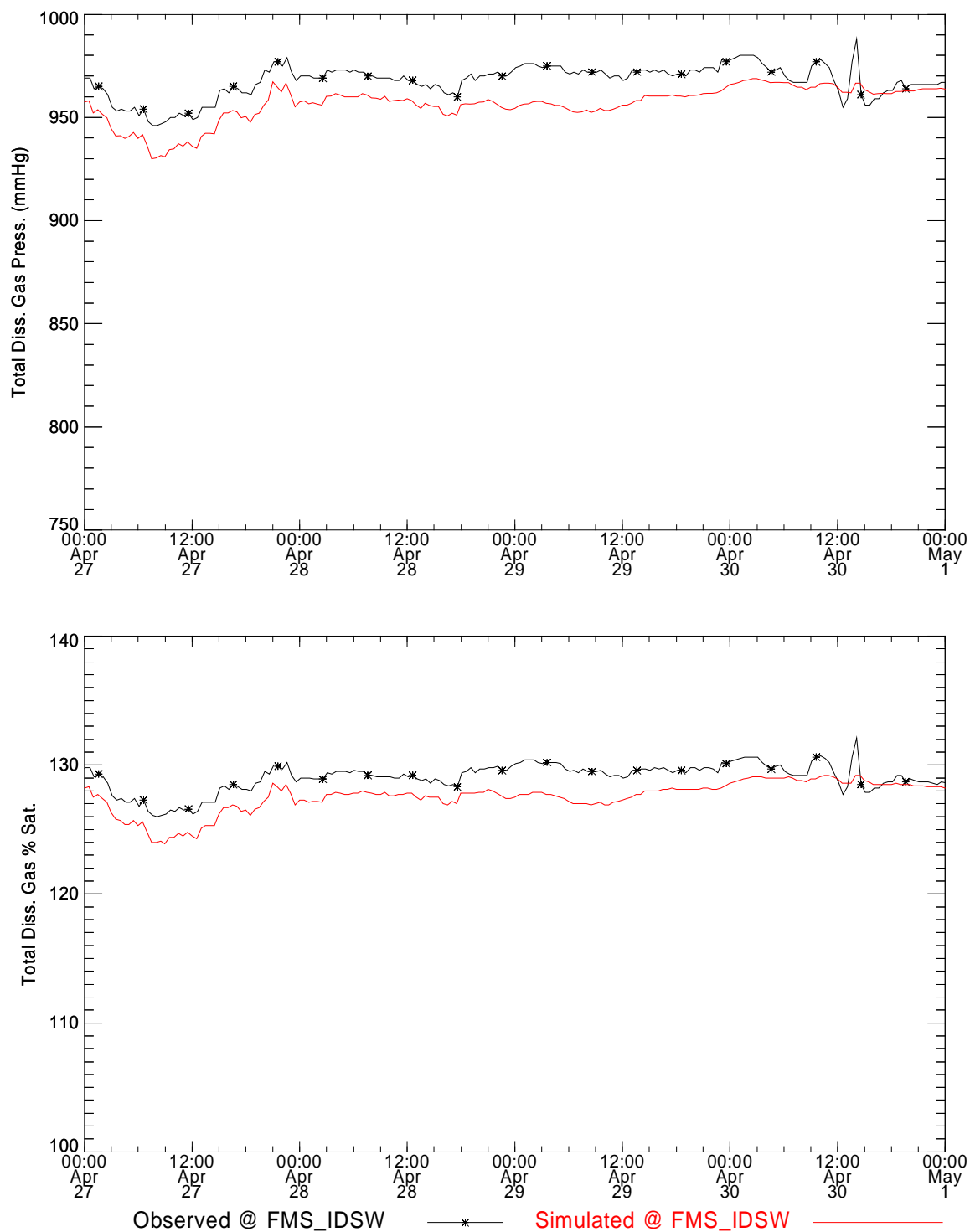
**Figure 136. Temperature and total dissolved gas time series comparisons near Snake River Mile 6.1 for the Spring 1997 pool study. These data were used for the upstream model water quality boundary conditions.**



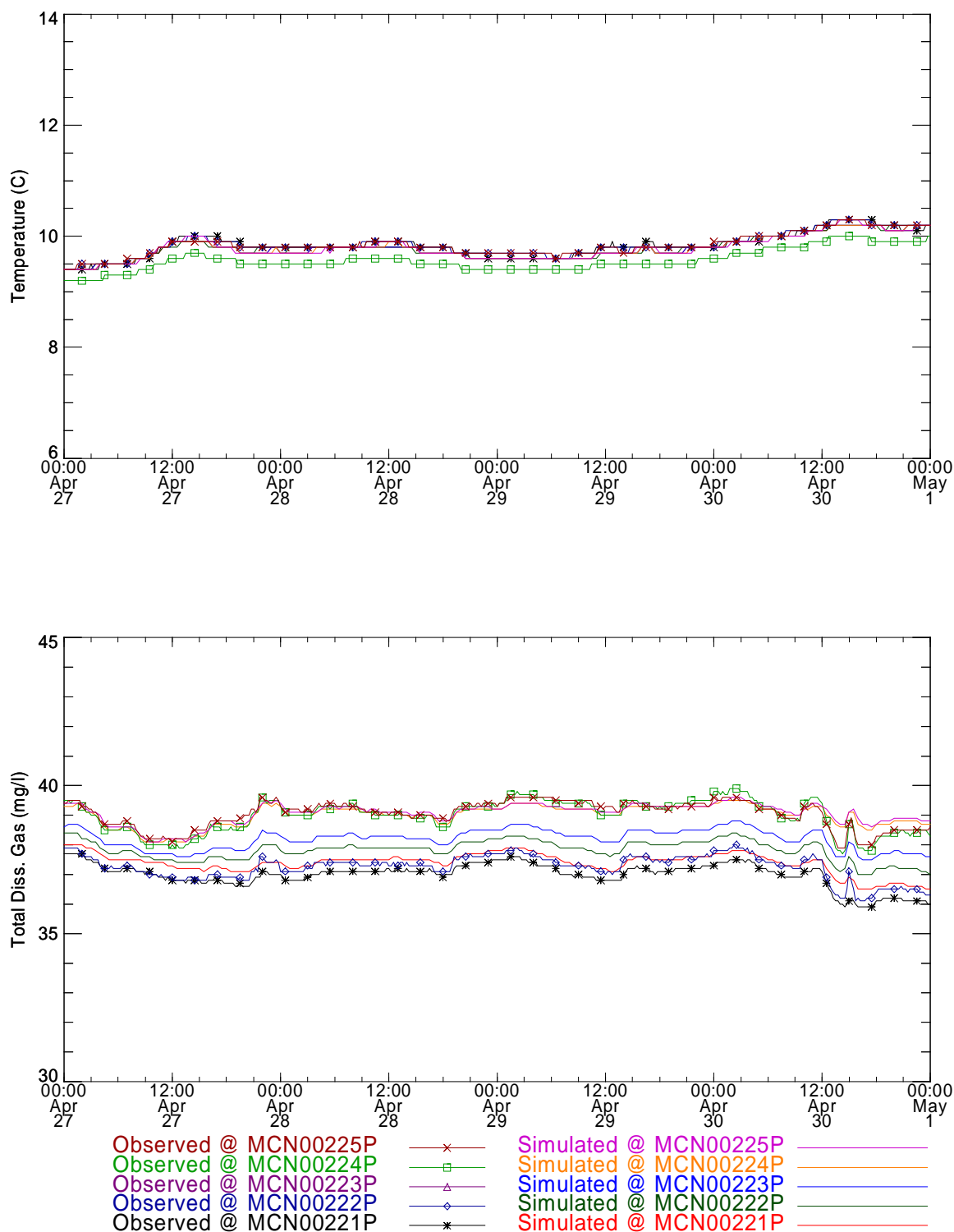
**Figure 137. Total dissolved gas time series comparisons near Snake River Mile 6.1 for the Spring 1997 pool study. These data were used for the upstream model water quality boundary conditions.**



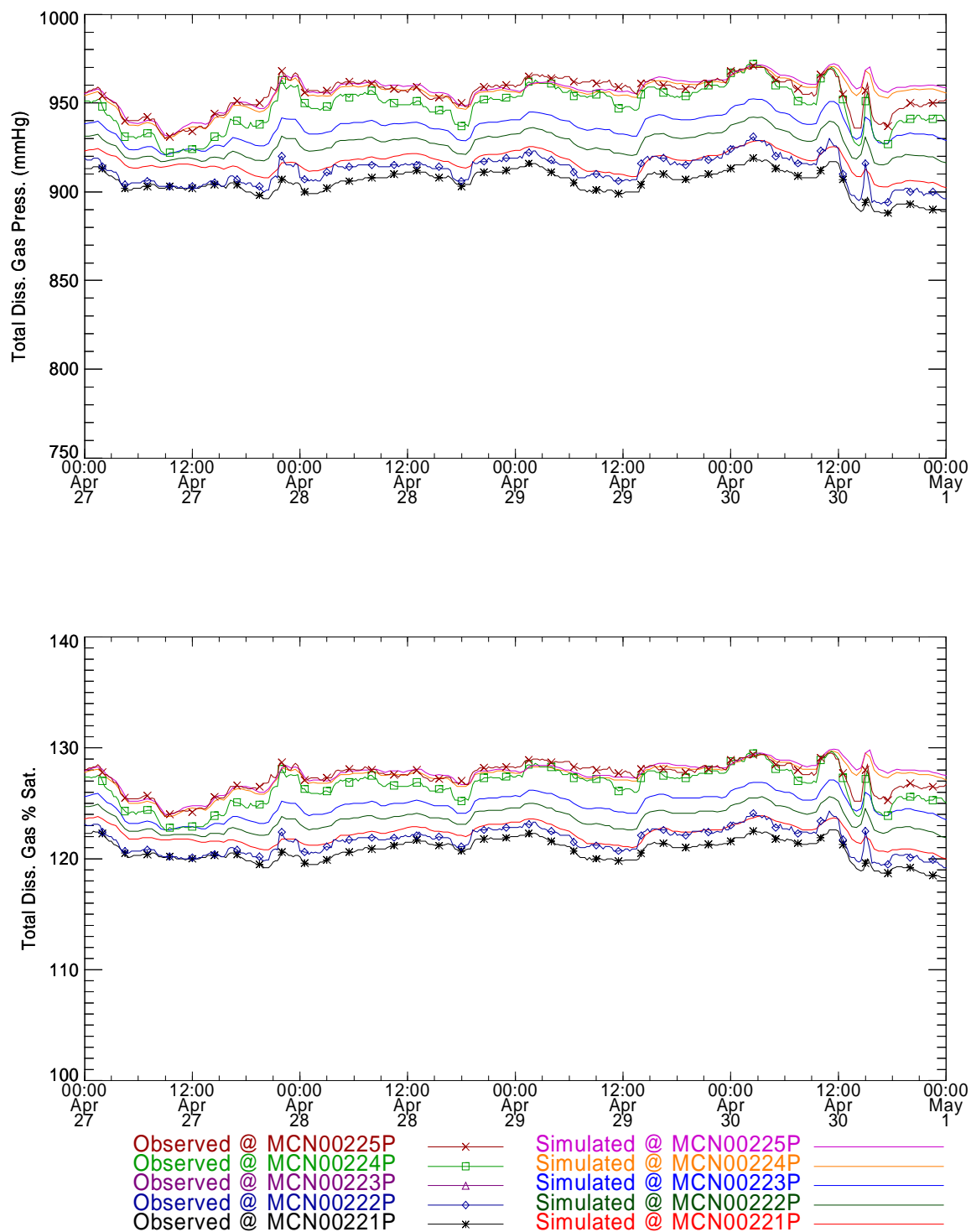
**Figure 138. Temperature and total dissolved gas time series comparisons near Ice Harbor Fixed Monitor for the Spring 1997 pool study.**



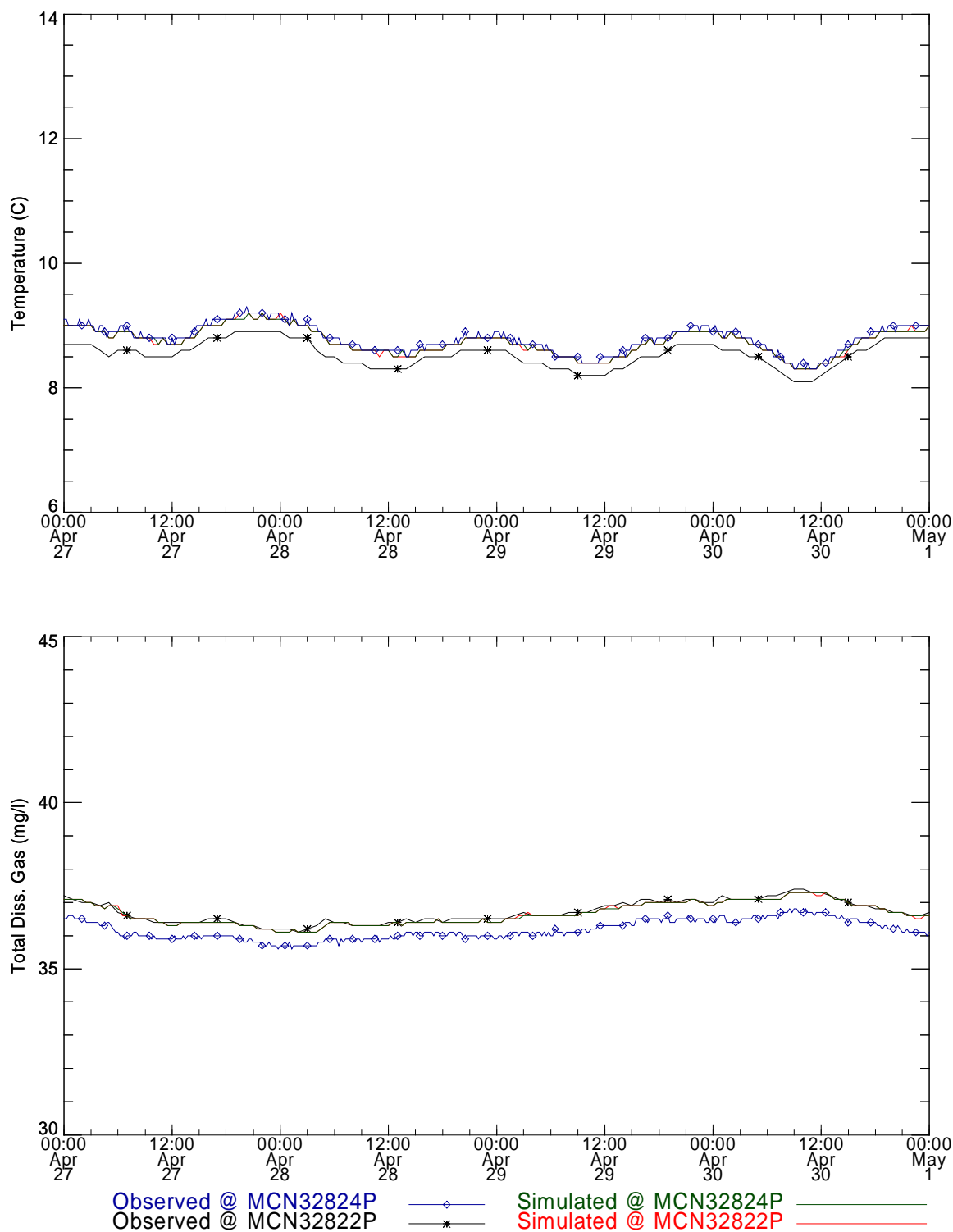
**Figure 139. Total dissolved gas time series comparisons near Ice Harbor Fixed Monitor for the Spring 1997 pool study.**



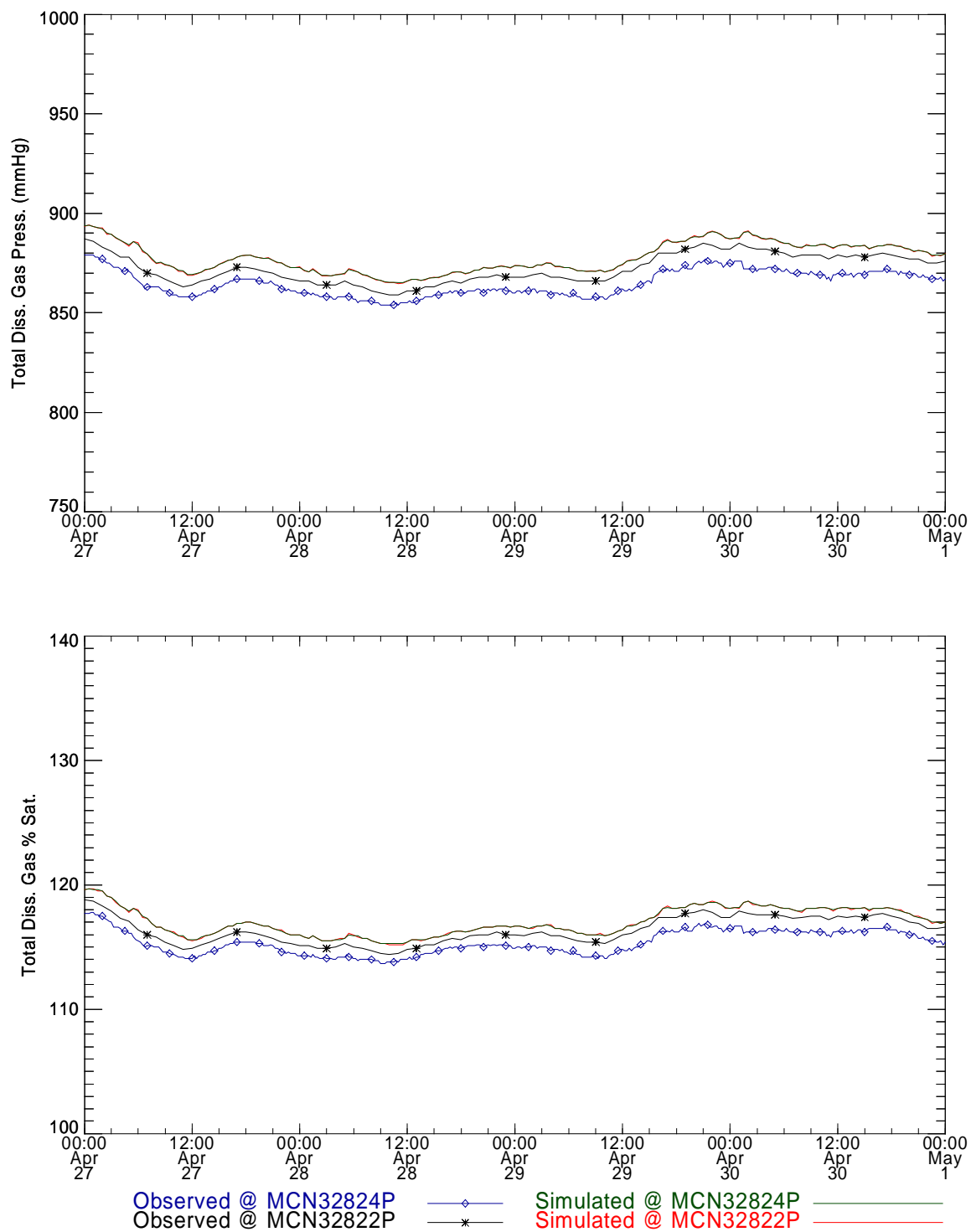
**Figure 140. Temperature and total dissolved gas time series comparisons near Snake River Mile 2.2 for the Spring 1997 pool study.**



**Figure 141. Total dissolved gas time series comparisons near Snake River Mile 2.2 for the Spring 1997 pool study.**

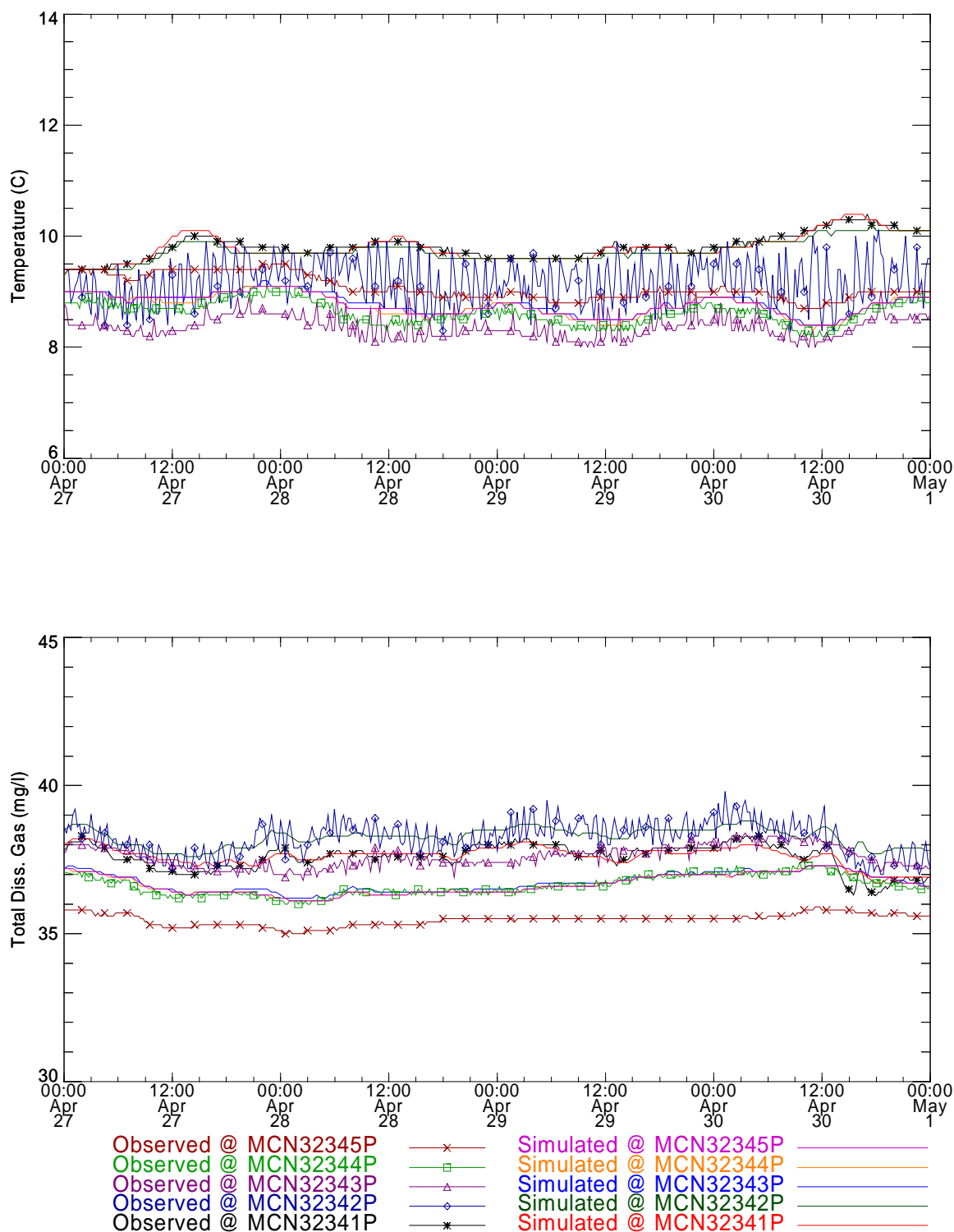


**Figure 142. Temperature and total dissolved gas time series comparisons near Columbia River Mile 328.2 for the Spring 1997 pool study. Note that station MCN32822 was used as the upstream water quality boundary condition.**

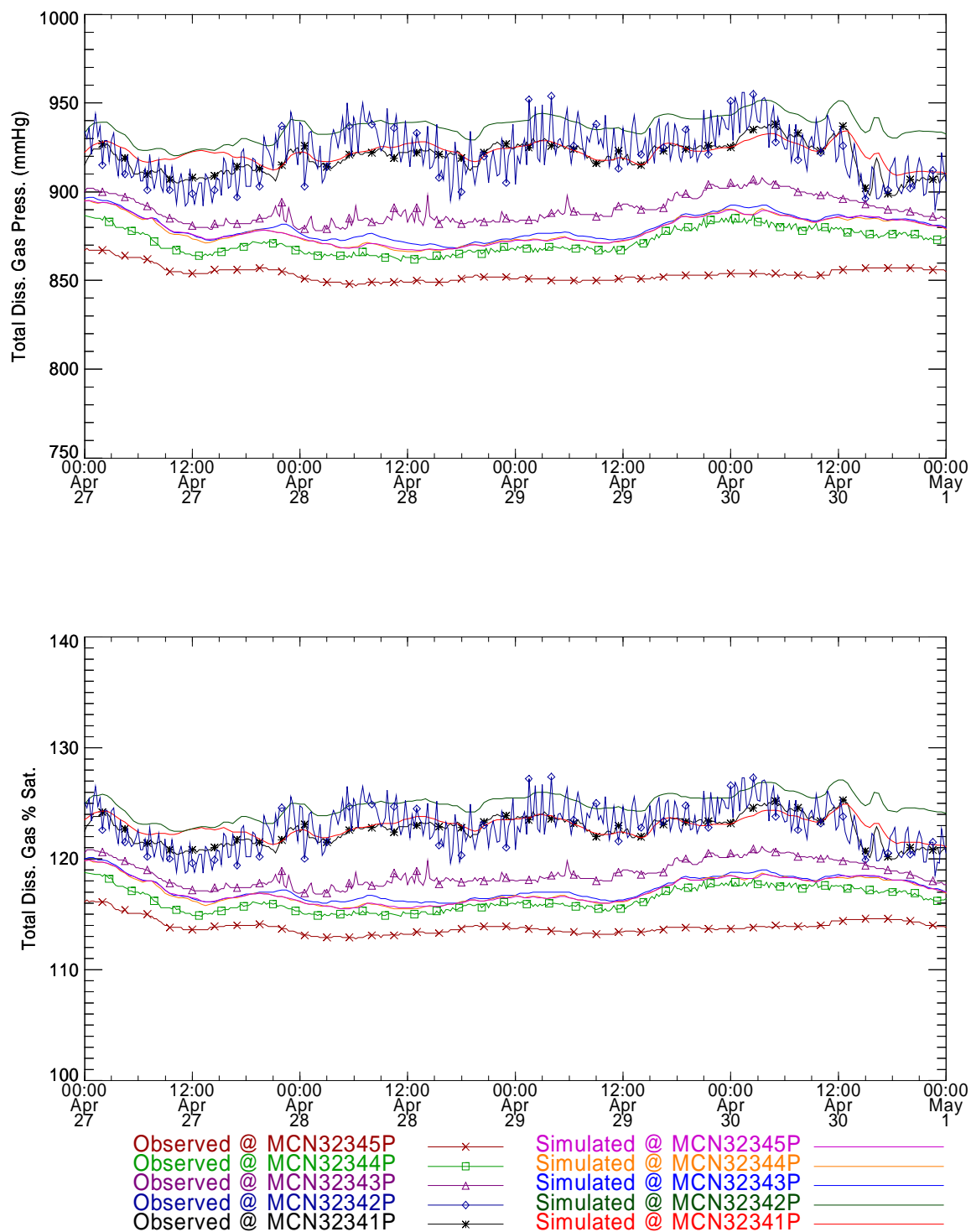


**Figure 143. Total dissolved gas time series comparisons near Columbia River Mile 328.2 for the Spring 1997 pool study. Note that station MCN32822 was used as the upstream water quality boundary condition.**

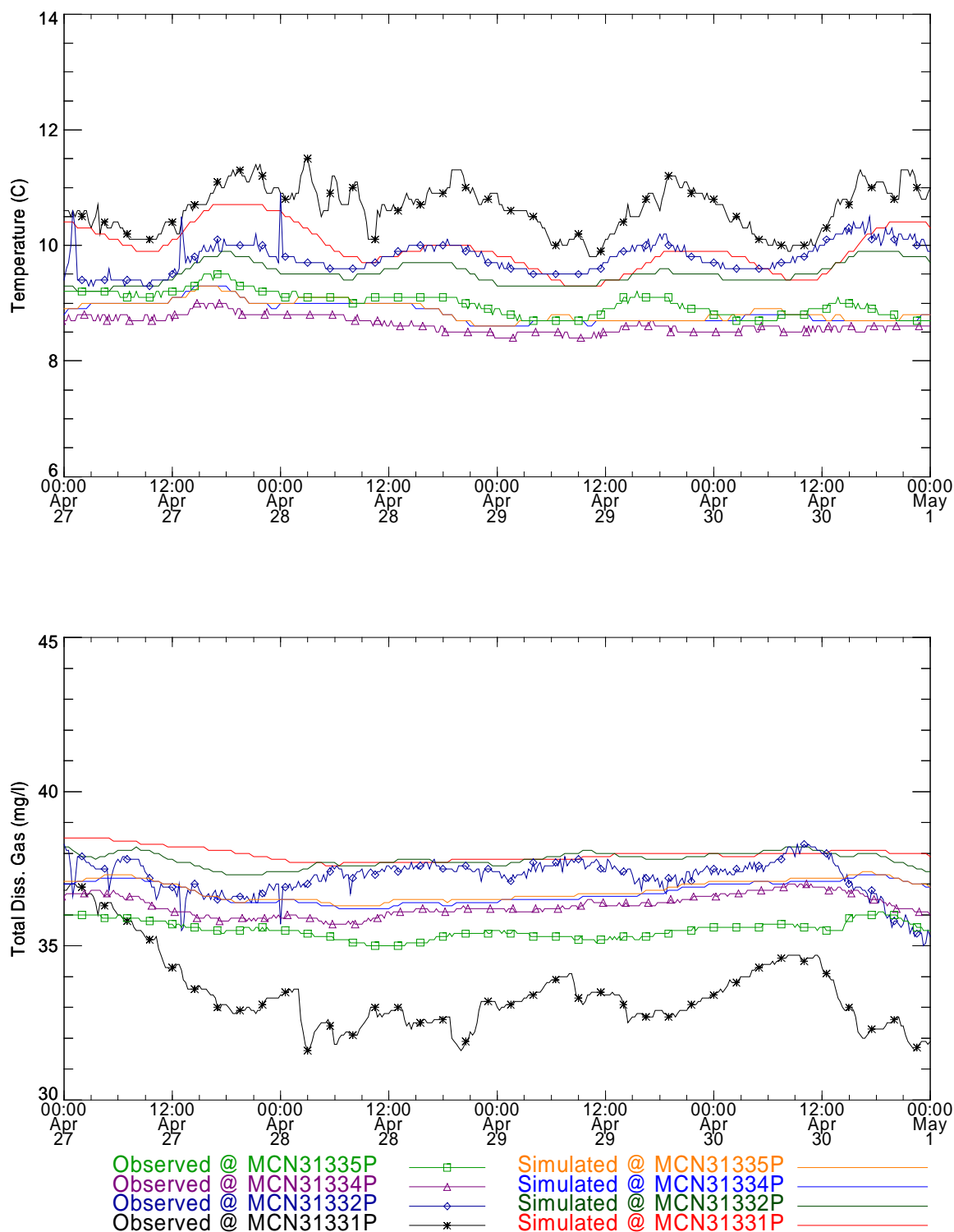




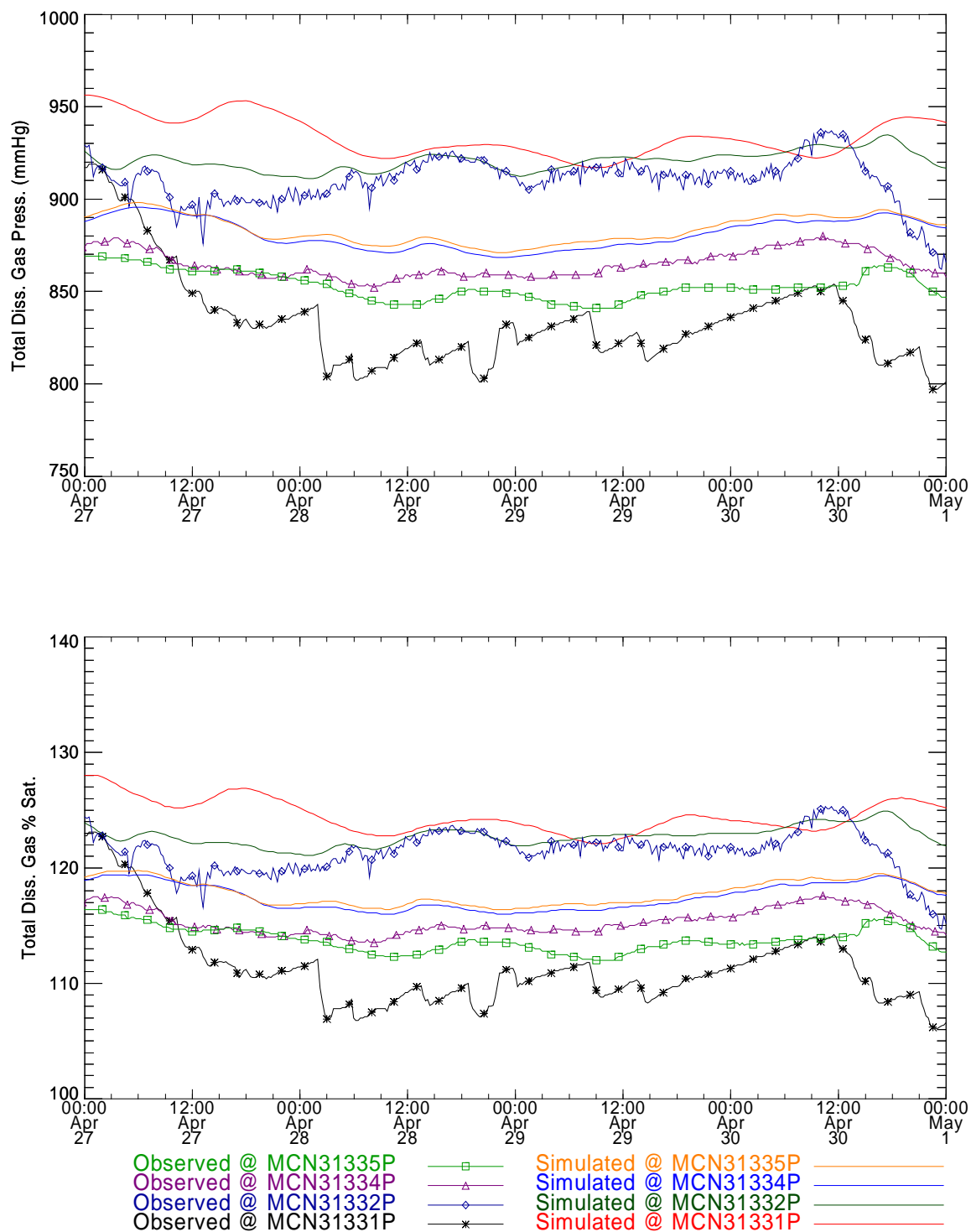
**Figure 144. Temperature and total dissolved gas time series comparisons near Columbia River Mile 323.4 for the Spring 1997 pool study.**



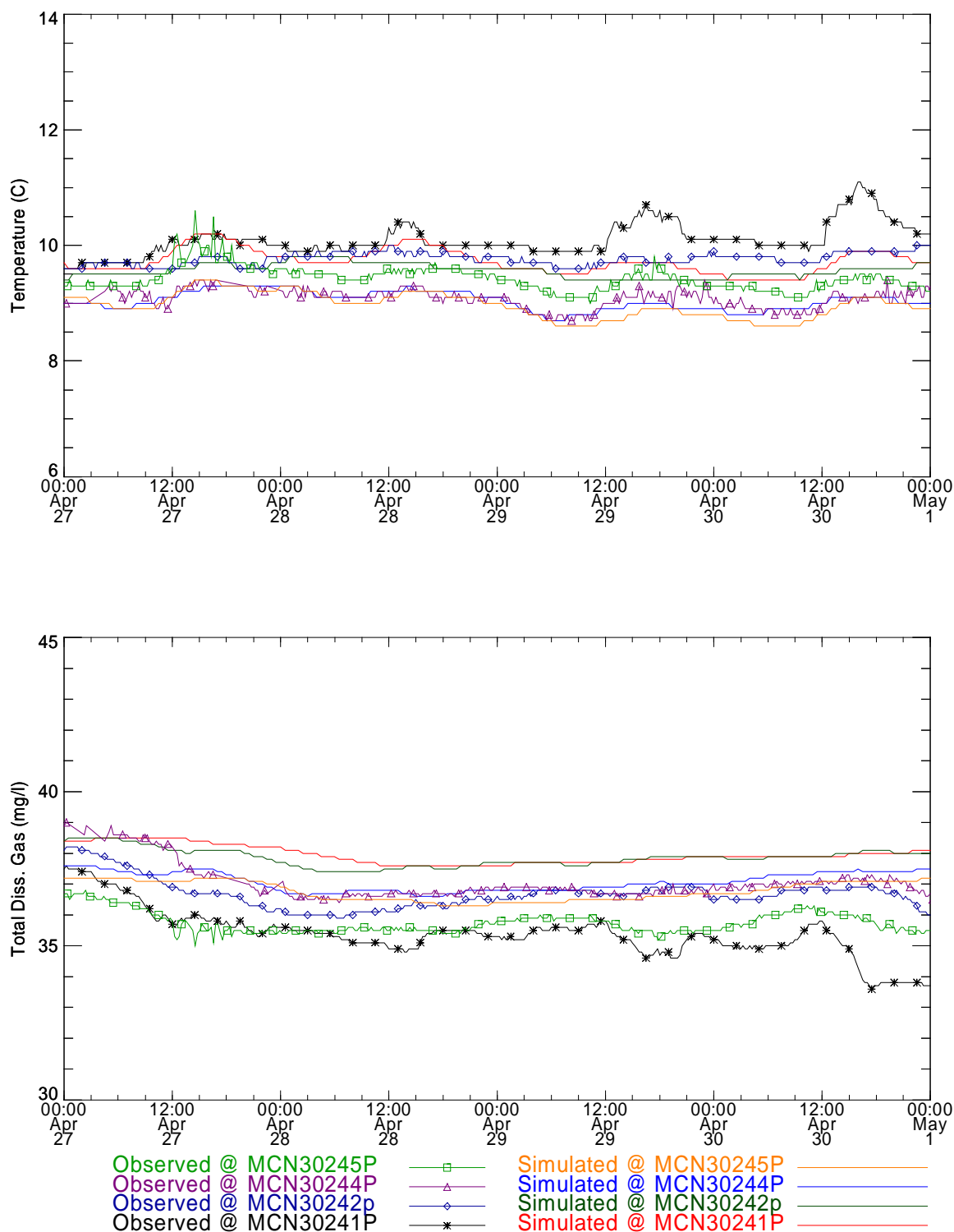
**Figure 145. Total dissolved gas time series comparisons near Columbia River Mile 323.4 for the Spring 1997 pool study.**



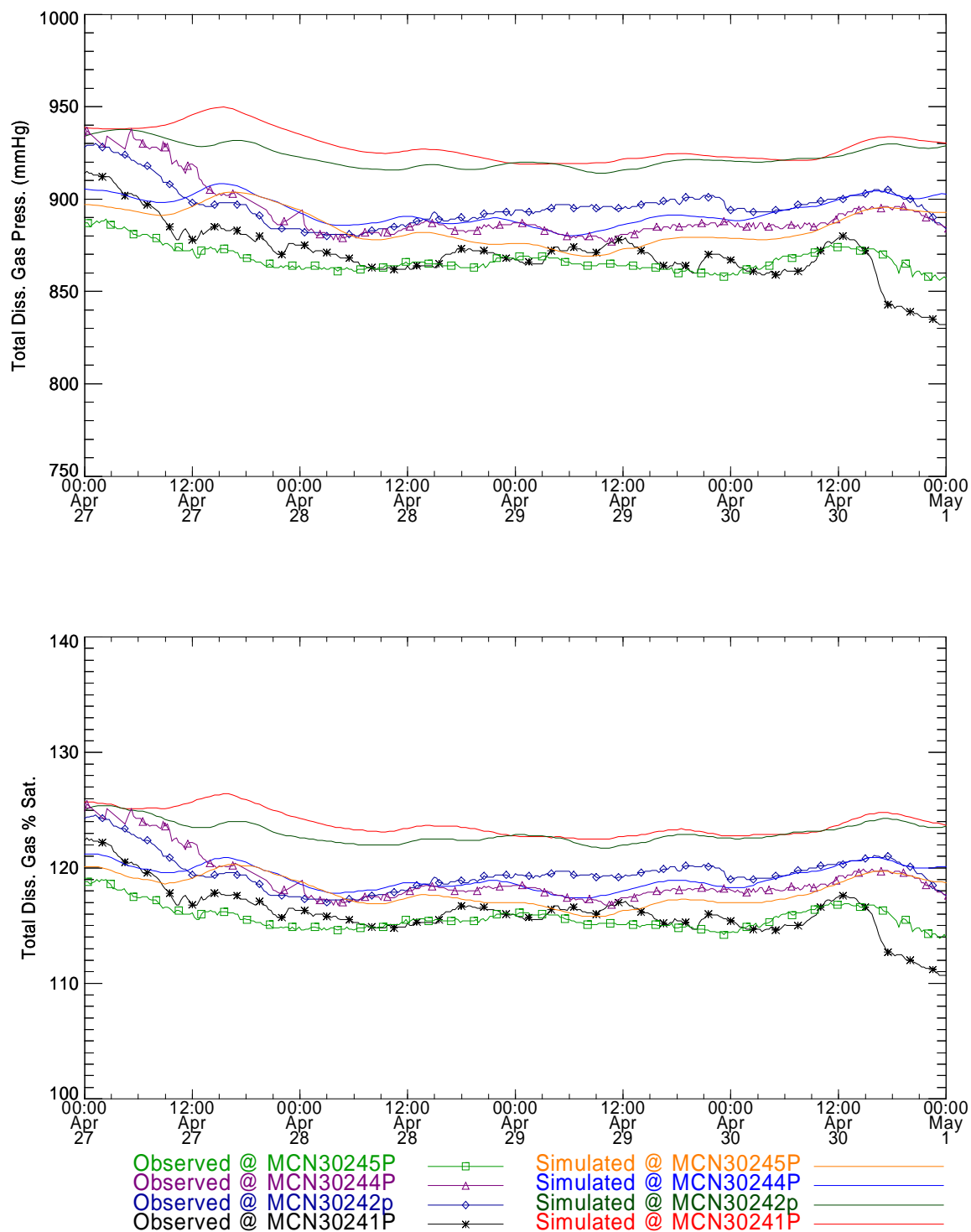
**Figure 146. Temperature and total dissolved gas time series comparisons near Columbia River Mile 313.3 for the Spring 1997 pool study.**



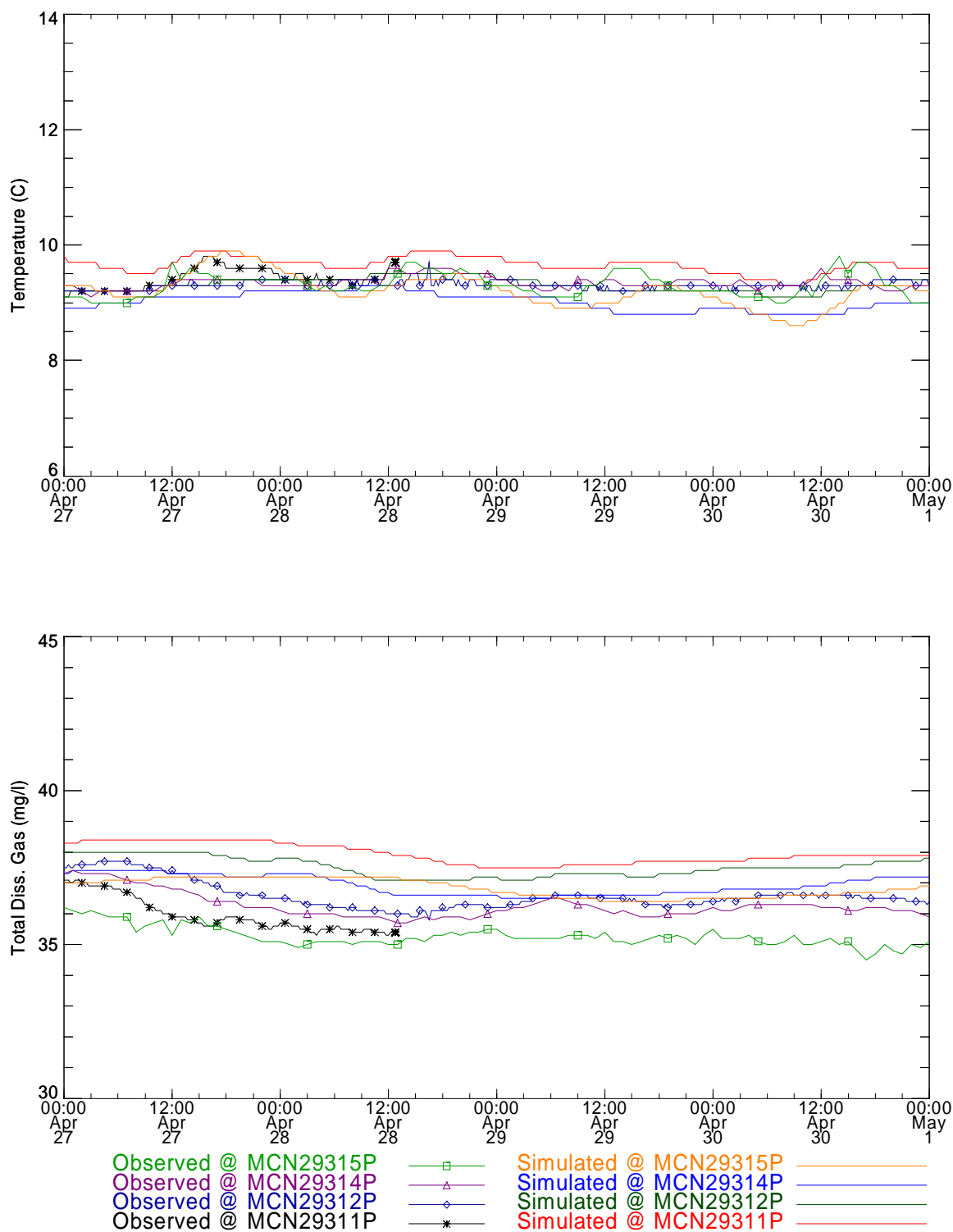
**Figure 147. Total dissolved gas time series comparisons near Columbia River Mile 313.3 for the Spring 1997 pool study.**



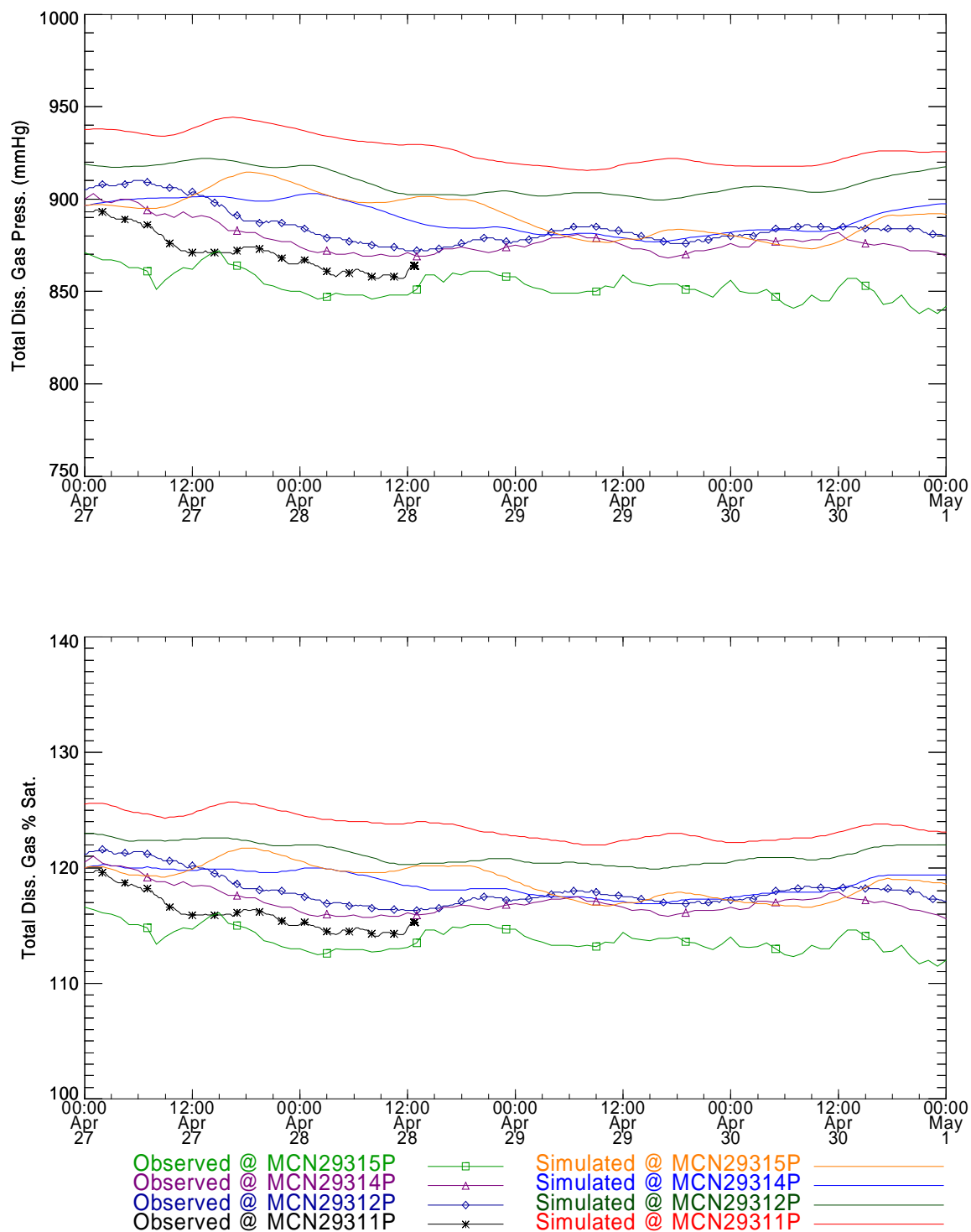
**Figure 148. Temperature and total dissolved gas time series comparisons near Columbia River Mile 302.4 for the Spring 1997 pool study.**



**Figure 149. Total dissolved gas time series comparisons near Columbia River Mile 302.4 for the Spring 1997 pool study.**

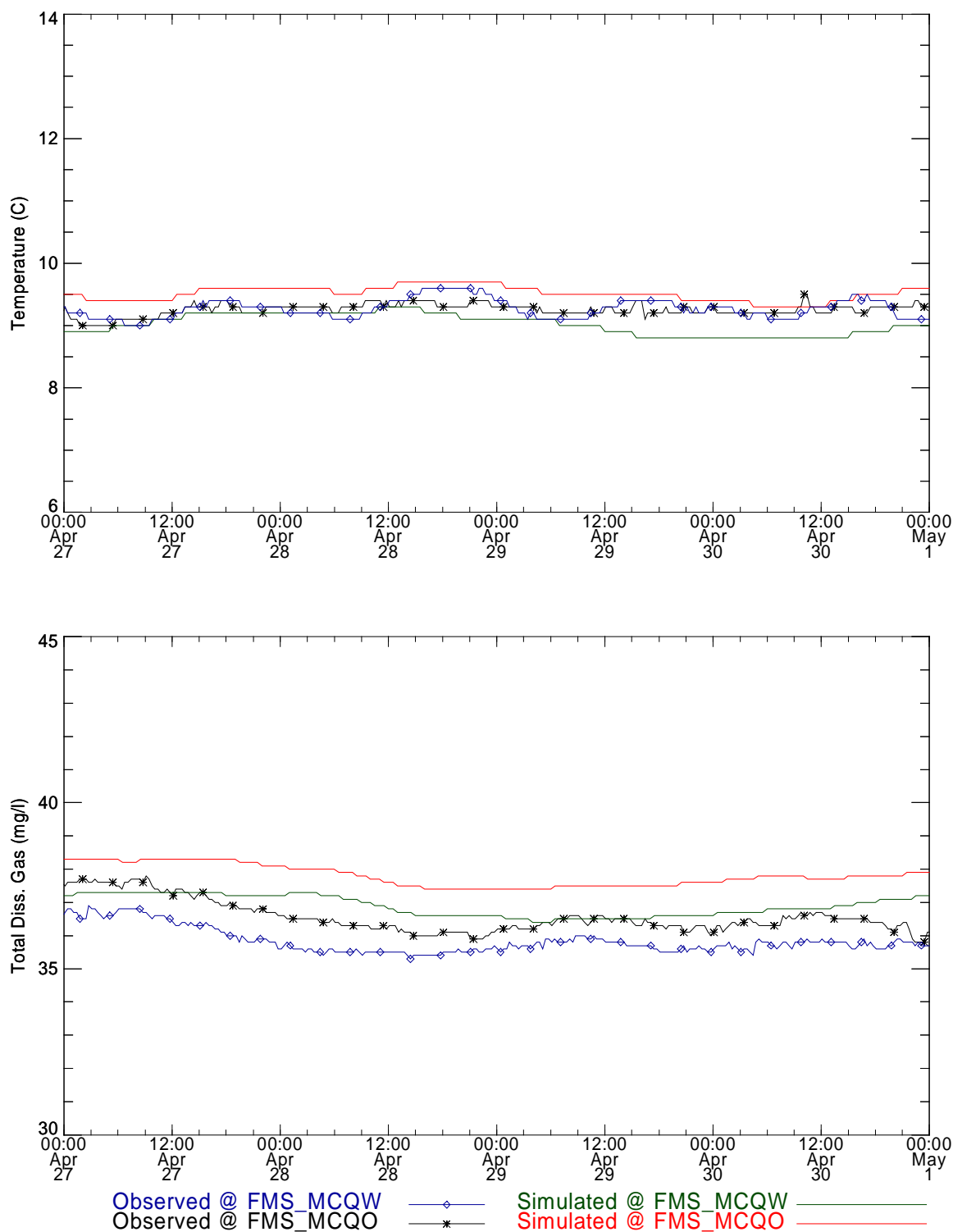


**Figure 150. Temperature and total dissolved gas time series comparisons near Columbia River Mile 293.4 for the Spring 1997 pool study.**

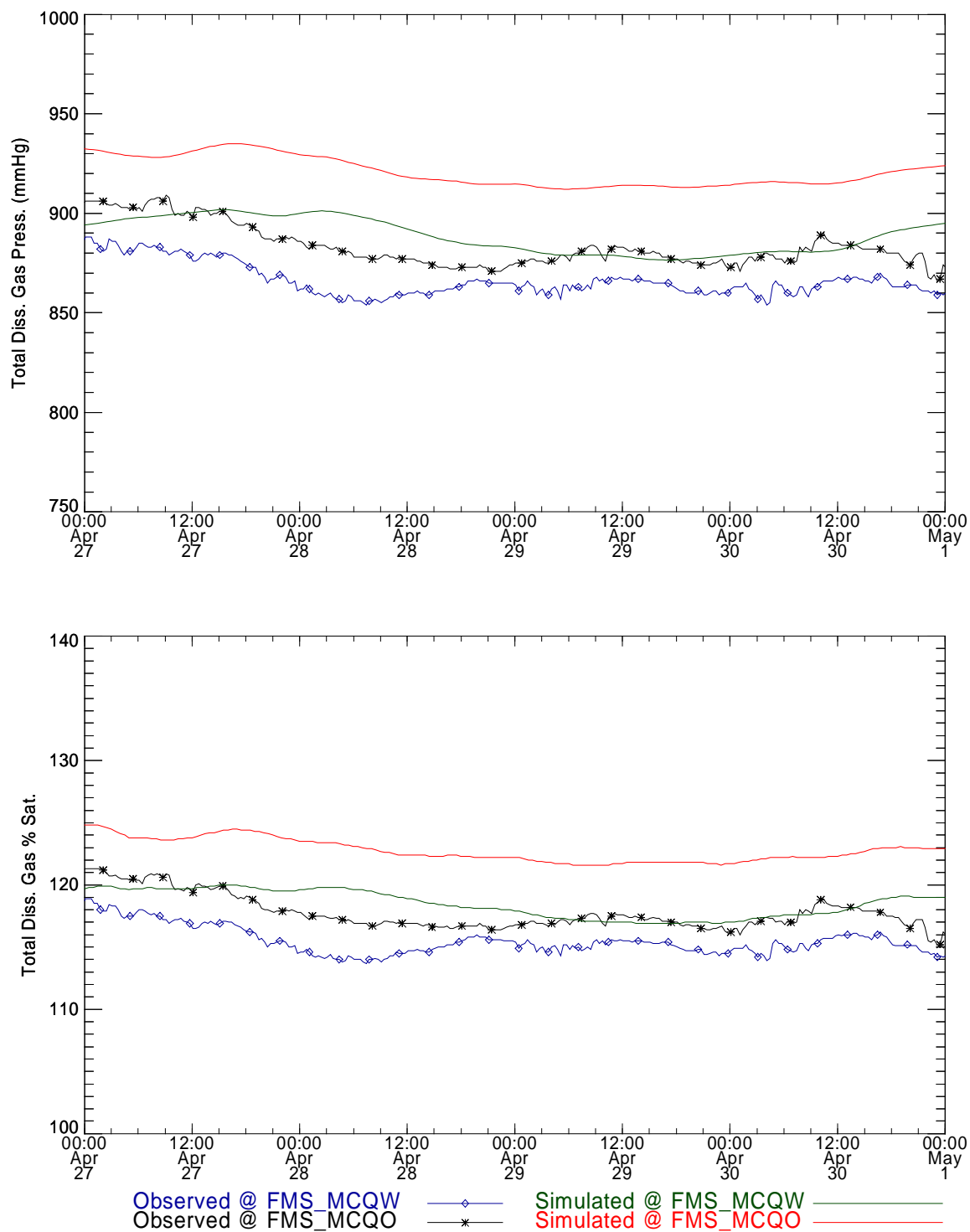


**Figure 151. Total dissolved gas time series comparisons near Columbia River Mile 293.4 for the Spring 1997 pool study.**





**Figure 152. Temperature and total dissolved gas time series comparisons at the McNary Forebay Fixed Monitors for the Spring 1997 pool study.**



**Figure 153. Total dissolved gas time series comparisons at the McNary Forebay Fixed Monitors for the Spring 1997 pool study.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_IDSW	9.69	9.64	0.32	0.34	0.07
Concentration (mg/l)					
FMS_IDSW	39.76	39.26	0.46	0.44	0.53
Gas Pressure (mmHg)					
FMS_IDSW	969.12	958.61	7.83	8.74	11.44
% Saturation					
FMS_IDSW	128.97	127.53	0.94	1.05	1.56

**Table 62. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_IDSW	100	100	100	100

**Table 63. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00221P	9.70	9.64	0.32	0.32	0.08
MCN00222P	9.70	9.64	0.32	0.33	0.08
MCN00223P	9.16	9.64	0.14	0.32	0.62
MCN00224P	9.43	9.64	0.32	0.32	0.22
MCN00225P	9.70	9.65	0.32	0.32	0.08
Concentration (mg/l)					
MCN00221P	37.23	37.62	0.60	0.56	0.41
MCN00222P	37.50	38.04	0.62	0.52	0.55
MCN00223P	38.59	38.40	0.14	0.50	0.54
MCN00224P	39.21	39.20	0.63	0.48	0.21
MCN00225P	39.26	39.27	0.55	0.47	0.19
Gas Pressure (mmHg)					
MCN00221P	908.06	919.02	9.28	8.12	11.11
MCN00222P	914.71	928.94	10.03	7.65	14.54
MCN00223P	929.13	937.91	3.66	7.86	11.28
MCN00224P	950.37	957.08	11.73	8.96	8.45
MCN00225P	957.40	958.88	9.52	8.98	4.89
% Saturation					
MCN00221P	120.84	122.26	1.20	1.05	1.44
MCN00222P	121.73	123.58	1.25	0.97	1.90
MCN00223P	123.18	124.78	0.41	0.99	1.88
MCN00224P	126.47	127.32	1.46	1.11	1.10
MCN00225P	127.41	127.57	1.14	1.11	0.64

**Table 64. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00221P	100	100	100	100
MCN00222P	100	100	100	100
MCN00223P	89.26	95.40	100	100
MCN00224P	100	100	100	100
MCN00225P	100	100	100	100

**Table 65. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN00622P	9.66	9.64	0.33	0.34	0.05
MCN00621P	9.69	9.64	0.33	0.34	0.09
MCN00623P	9.69	9.64	0.33	0.34	0.07
MCN00625P	9.73	9.64	0.33	0.34	0.09
Concentration (mg/l)					
MCN00622P	37.47	37.42	0.55	0.55	0.07
MCN00621P	37.29	37.24	0.64	0.64	0.07
MCN00623P	39.46	39.38	0.56	0.57	0.09
MCN00625P	39.31	39.26	0.44	0.44	0.07
Gas Pressure (mmHg)					
MCN00622P	913.06	913.94	8.28	8.19	1.18
MCN00621P	909.54	909.77	9.66	9.33	1.44
MCN00623P	962.00	961.53	11.25	11.14	0.64
MCN00625P	959.11	958.61	8.73	8.74	0.64
% Saturation					
MCN00622P	121.50	121.58	1.07	1.06	0.14
MCN00621P	121.04	121.03	1.25	1.21	0.19
MCN00623P	128.02	127.92	1.42	1.41	0.12
MCN00625P	127.63	127.53	1.04	1.05	0.13

**Table 66. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN00622P	100	100	100	100
MCN00621P	100	100	100	100
MCN00623P	100	100	100	100
MCN00625P	100	100	100	100

**Table 67. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature(°C)					
MCN32822P	8.53	8.75	0.21	0.21	0.22
MCN32824P	8.79	8.75	0.21	0.21	0.07
Concentration (mg/l)					
MCN32822P	36.75	36.71	0.33	0.33	0.08
MCN32824P	36.22	36.71	0.29	0.33	0.50
Gas Pressure (mmHg)					
MCN32822P	873.29	878.80	7.47	7.77	5.70
MCN32824P	865.84	878.83	6.80	7.73	13.11
% Saturation					
MCN32822P	116.46	117.15	1.15	1.18	0.73
MCN32824P	115.47	117.16	1.07	1.18	1.71

**Table 68. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32822P	100	100	100	100
MCN32824P	100	100	100	100

**Table 69. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN32344P	8.62	8.76	0.19	0.19	0.15
MCN32342P	9.80	9.78	0.27	0.27	0.07
MCN32343P	9.16	9.72	0.38	0.25	0.69
MCN32341P	8.36	8.79	0.19	0.18	0.45
MCN32345P	9.09	8.77	0.22	0.18	0.35
Concentration (mg/l)					
MCN32344P	36.66	36.71	0.32	0.33	0.13
MCN32342P	37.60	37.64	0.53	0.47	0.19
MCN32343P	38.26	38.27	0.58	0.38	0.39
MCN32341P	37.63	36.76	0.35	0.32	0.88
MCN32345P	35.50	36.71	0.19	0.33	1.23
Gas Pressure (mmHg)					
MCN32344P	872.80	879.10	6.90	7.63	6.66
MCN32342P	919.23	922.26	9.67	8.01	5.87
MCN32343P	921.98	936.28	14.62	7.62	18.29
MCN32341P	890.23	880.90	7.17	7.21	10.26
MCN32345P	854.70	879.31	4.80	7.60	25.08
% Saturation					
MCN32344P	116.39	117.19	1.06	1.16	0.85
MCN32342P	122.58	122.95	1.38	1.19	0.76
MCN32343P	122.95	124.82	1.97	1.10	2.41
MCN32341P	118.71	117.43	1.10	1.10	1.40
MCN32345P	113.98	117.22	0.78	1.15	3.31

**Table 70. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN32344P	100	100	100	100
MCN32342P	100	100	100	100
MCN32343P	87.29	100	99.15	99.15
MCN32341P	100	84.32	100	100
MCN32345P	100	25.42	100	100

**Table 71. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN31334P	8.58	8.80	0.17	0.19	0.23
MCN31332P	10.54	10.04	0.40	0.38	0.64
MCN31331P	9.74	9.44	0.28	0.23	0.36
MCN31335P	8.96	8.82	0.23	0.18	0.23
Concentration (mg/l)					
MCN31334P	36.41	36.8	0.36	0.31	0.44
MCN31332P	34.08	37.96	1.70	0.32	4.18
MCN31331P	37.44	37.96	0.83	0.39	0.76
MCN31335P	35.61	36.89	0.30	0.31	1.29
Gas Pressure (mmHg)					
MCN31334P	866.14	881.96	7.54	7.67	16.57
MCN31332P	847.81	935.4	38.39	10.99	93.61
MCN31331P	914.24	922.92	18.12	7.11	16.30
MCN31335P	854.81	884.65	8.93	7.16	30.44
% Saturation					
MCN31334P	115.34	117.41	1.17	1.19	2.17
MCN31332P	112.90	124.53	5.10	1.58	12.43
MCN31331P	121.75	122.87	2.43	1.04	2.15
MCN31335P	113.83	117.77	1.31	1.11	4.02

**Table 72. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN31334P	100	100	100	100
MCN31332P	93.81	0	7.56	7.90
MCN31331P	98.63	83.85	92.44	92.78
MCN31335P	100	11.00	87.97	88.32

**Table 73. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**



Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN30245P	9.38	8.92	0.23	0.22	0.48
MCN30242P	9.75	9.55	0.12	0.13	0.23
MCN30244P	9.05	9.00	0.17	0.16	0.14
MCN30241P	10.02	9.74	0.29	0.20	0.44
Concentration (mg/l)					
MCN30245P	35.83	36.86	0.39	0.32	1.11
MCN30242P	36.81	37.94	0.73	0.32	1.24
MCN30244P	37.21	37.17	0.74	0.32	0.58
MCN30241P	35.64	38.01	1.15	0.28	2.59
Gas Pressure (mmHg)					
MCN30245P	868.45	885.93	8.50	9.01	20.13
MCN30242P	899.26	924.96	16.01	6.66	28.69
MCN30244P	894.44	894.97	17.02	7.31	13.24
MCN30241P	875.92	930.49	23.98	8.64	58.44
% Saturation					
MCN30245P	115.76	118.05	1.27	1.26	2.65
MCN30242P	119.87	123.26	2.22	0.92	3.79
MCN30244P	119.22	119.26	2.36	1.06	1.76
MCN30241P	116.76	123.99	3.25	1.19	7.75

**Table 74. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN30245P	99.61	58.20	98.05	97.66
MCN30242P	100	39.84	85.55	85.94
MCN30244P	100	85.94	100	100
MCN30241P	99.22	18.75	23.44	23.44

**Table 75. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
MCN29311P	9.53	9.68	0.24	0.16	0.37
MCN29312P	9.29	9.29	0.09	0.12	0.09
MCN29314P	9.34	8.99	0.10	0.16	0.39
MCN29315P	9.29	9.18	0.22	0.28	0.29
Concentration (mg/l)					
MCN29311P	35.77	37.95	0.59	0.30	2.24
MCN29312P	36.69	37.59	0.55	0.32	0.98
MCN29314P	36.34	36.99	0.52	0.31	0.79
MCN29315P	35.37	36.84	0.48	0.28	1.57
Gas Pressure (mmHg)					
MCN29311P	869.51	927.63	10.12	8.12	58.76
MCN29312P	886.84	910.61	11.90	7.06	25.46
MCN29314P	879.80	890.51	11.48	7.92	16.10
MCN29315P	855.55	890.79	12.31	10.89	38.35
% Saturation					
MCN29311P	115.97	123.65	1.43	1.10	7.77
MCN29312P	118.25	121.38	1.66	0.92	3.36
MCN29314P	117.31	118.70	1.63	1.01	2.12
MCN29315P	114.08	118.74	1.74	1.45	5.07

**Table 76. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
MCN29311P	99.59	4.15	0	0
MCN29312P	100	66.80	93.36	93.36
MCN29314P	100	80.91	100	100
MCN29315P	100	17.84	60.17	60.17

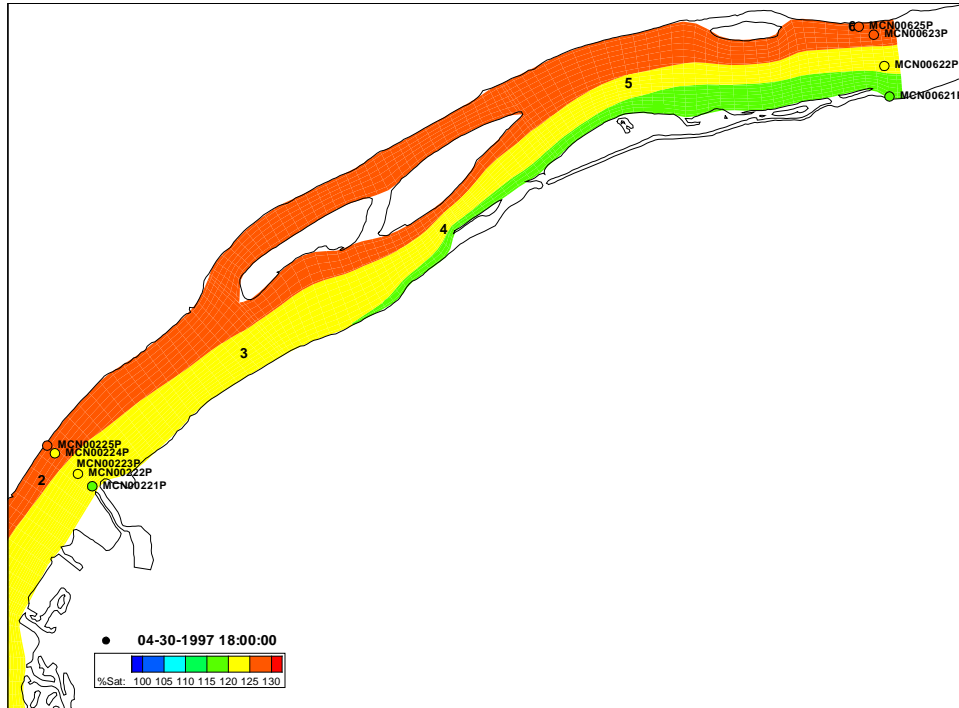
**Table 77. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_MCQW	9.26	8.98	0.18	0.17	0.36
FMS_MCQO	9.26	9.52	0.18	0.11	0.31
Concentration (mg/l)					
FMS_MCQW	35.94	36.94	0.50	0.30	1.10
FMS_MCQO	36.67	37.84	0.55	0.30	1.24
Gas Pressure (mmHg)					
FMS_MCQW	868.75	889.03	12.11	8.10	24.21
FMS_MCQO	886.10	921.81	12.99	7.10	37.02
% Saturation					
FMS_MCQW	115.79	118.49	1.73	1.04	3.24
FMS_MCQO	118.10	122.86	1.80	0.95	4.94

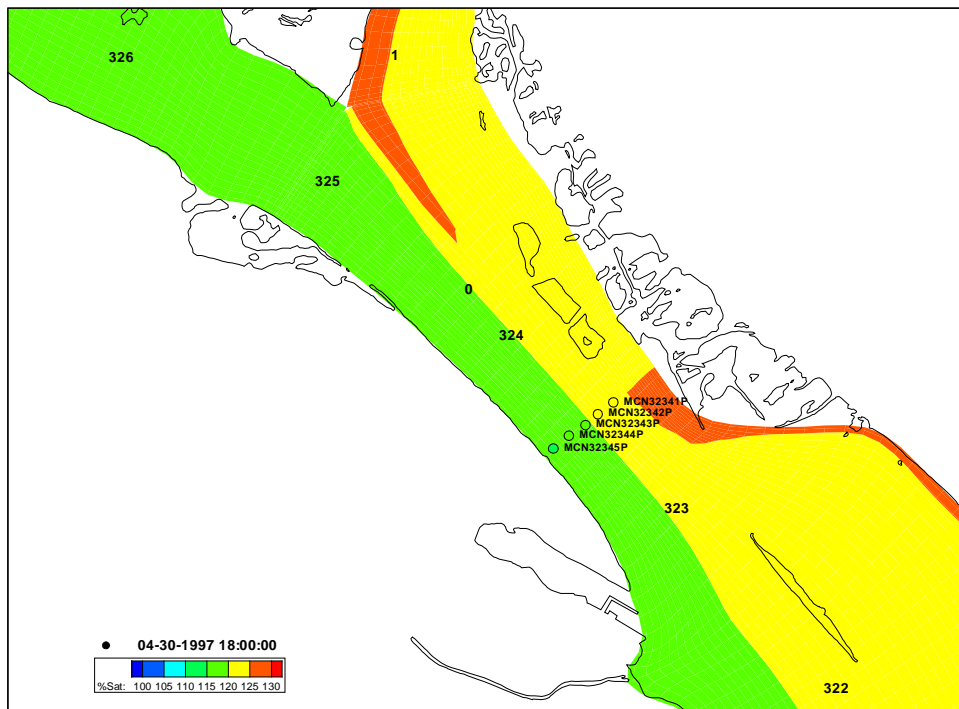
**Table 78. Statistical summary of measurements and simulations for the Spring 1997 pool study.**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_MCQW	100	52.03	86.59	85.77
FMS_MCQO	100	31.30	53.66	50.81

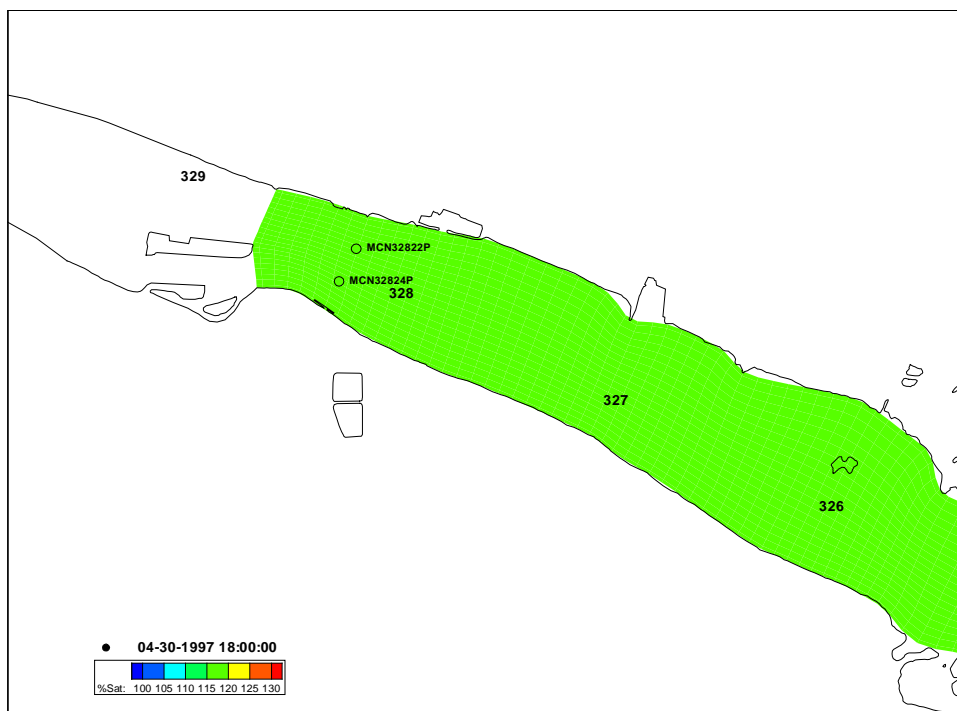
**Table 79. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements.**



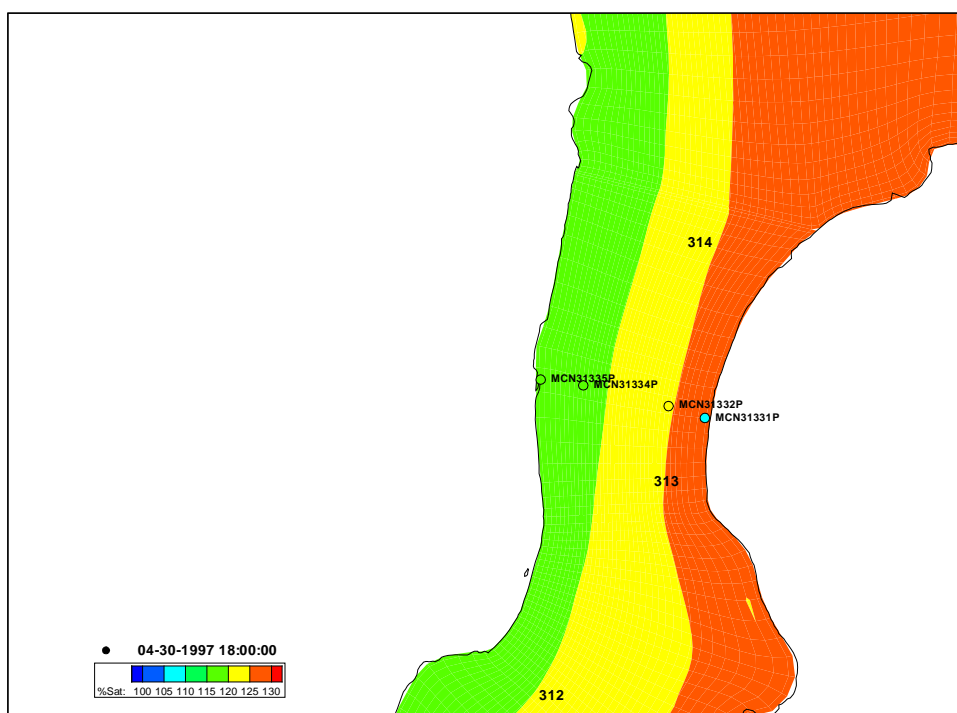
**Figure 154. Simulated total dissolved gas saturation distribution in the Snake River. The monitors are color coded to their measured temperature.**



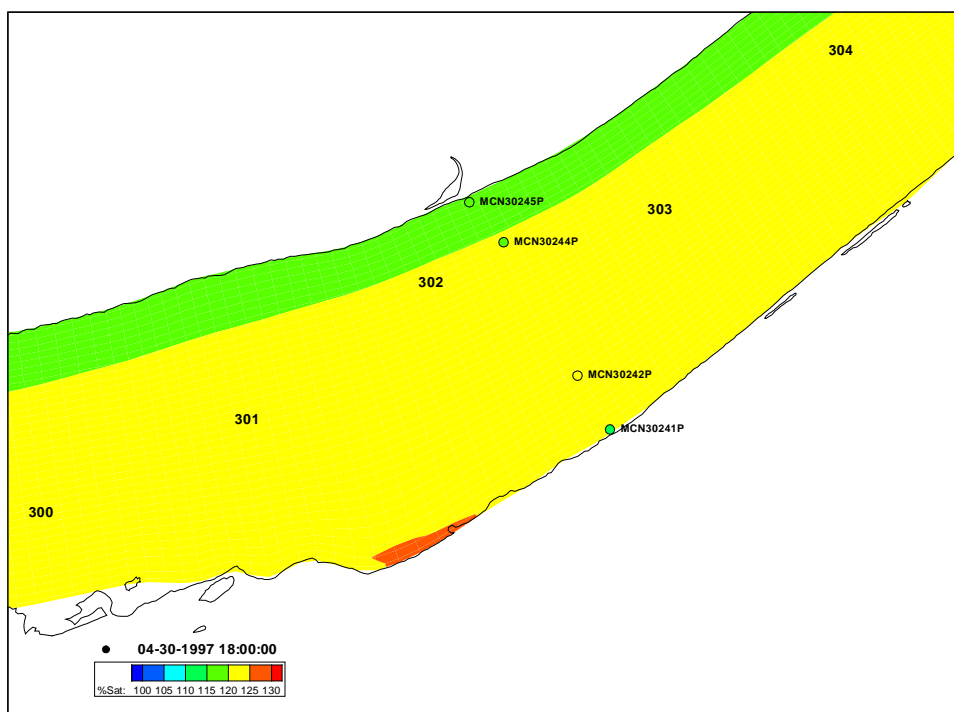
**Figure 155. Simulated total dissolved gas saturation distribution at the confluence of the Columbia and Snake Rivers. The monitors are color coded to their measured temperature.**



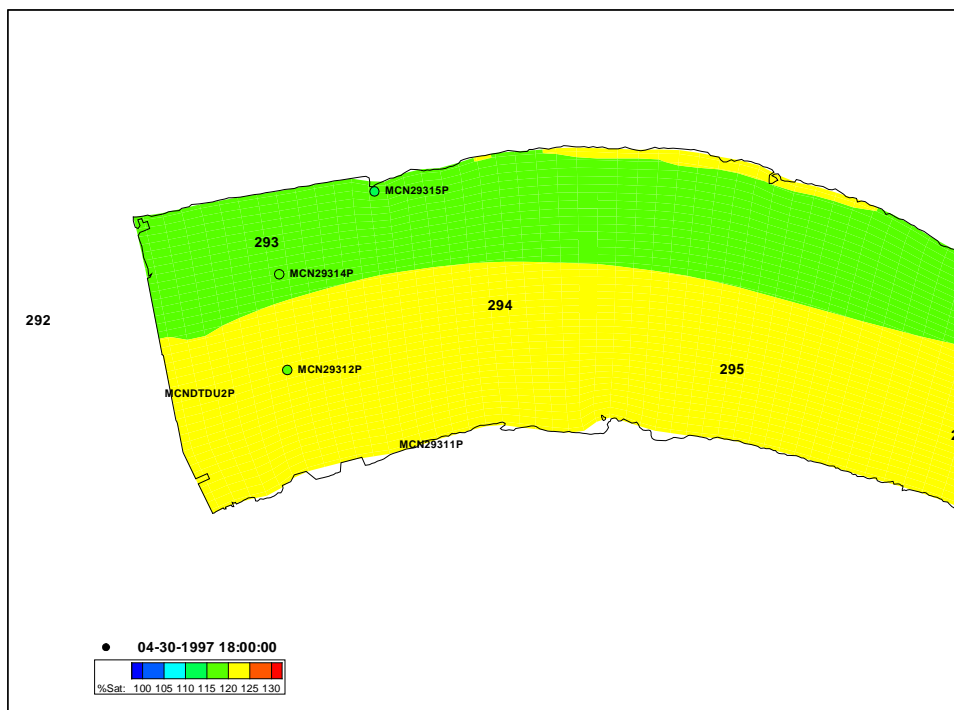
**Figure 156. Simulated total dissolved gas saturation distribution in the Columbia River. The monitors are color coded to their measured temperature.**



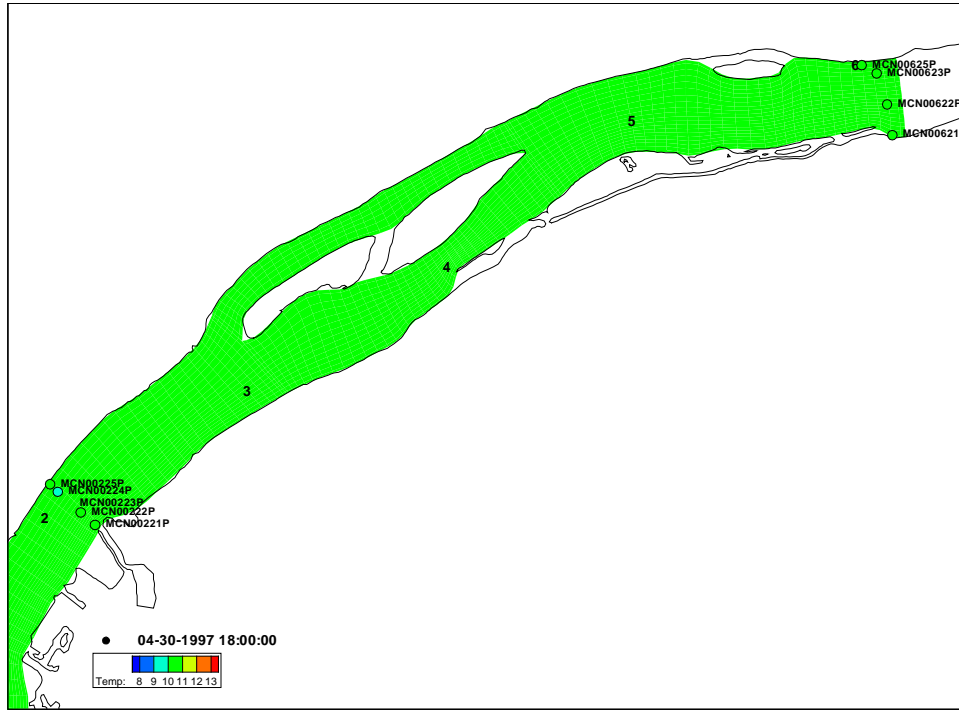
**Figure 157. Simulated total dissolved gas saturation distribution in the Columbia River. The monitors are color coded to their measured temperature.**



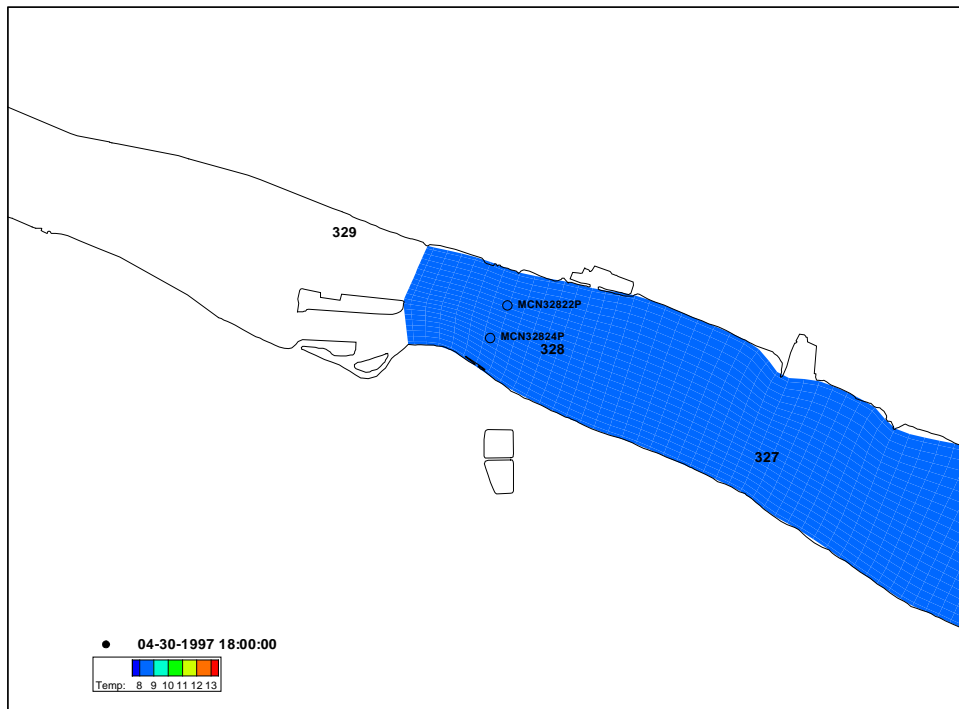
**Figure 158. Simulated total dissolved gas saturation distribution in the Columbia River. The monitors are color coded to their measured temperature.**



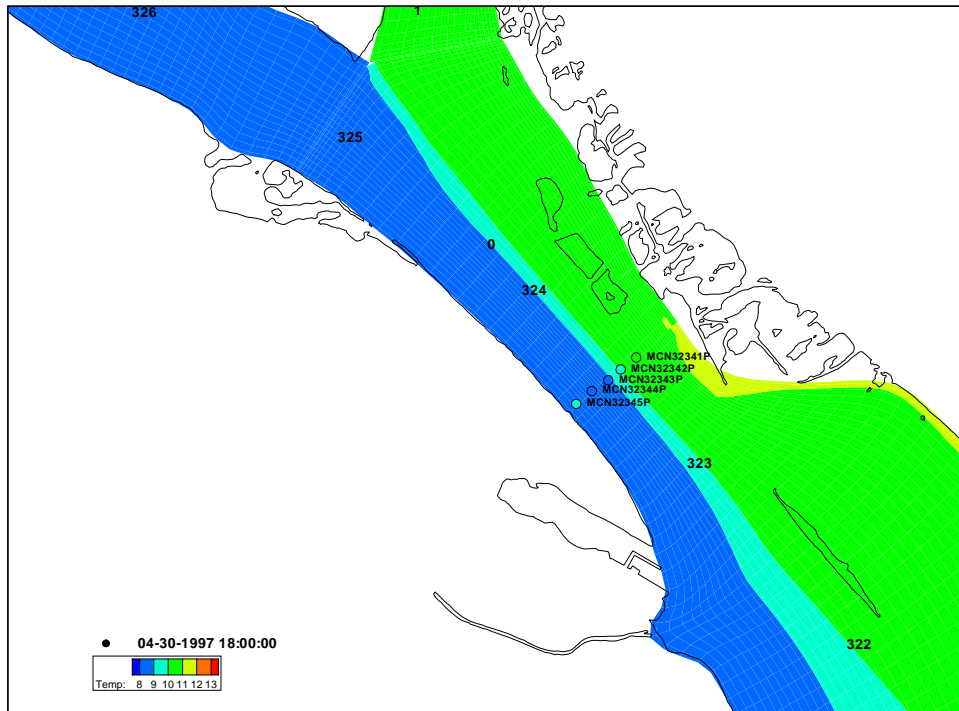
**Figure 159. Simulated total dissolved gas saturation distribution in the Columbia River. The monitors are color coded to their measured temperature.**



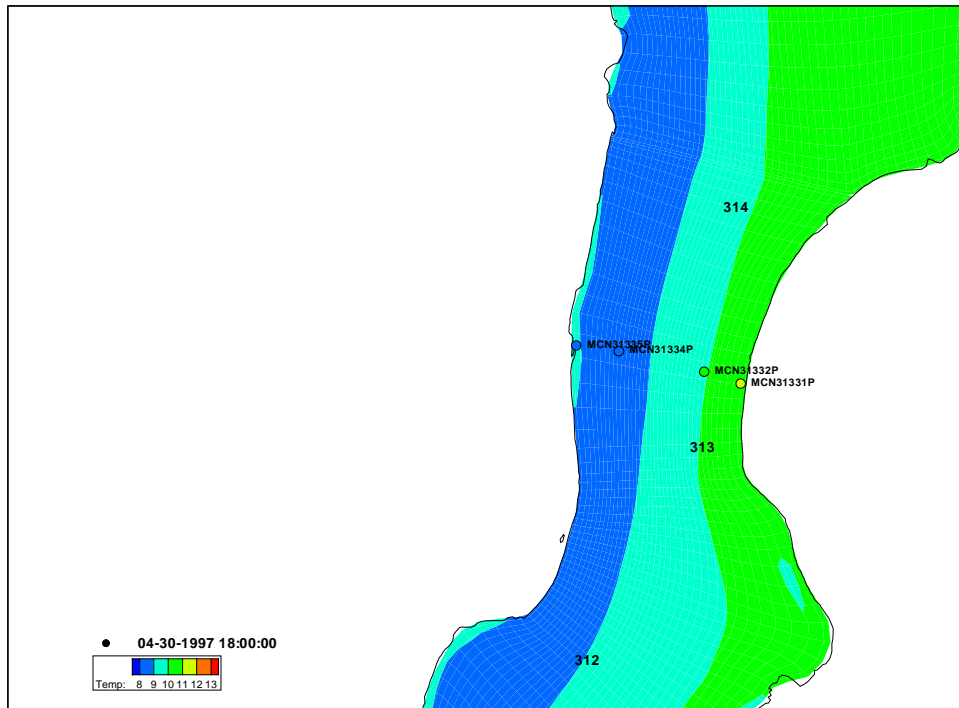
**Figure 160. Simulated temperature distribution in the Snake River. The monitors are color coded to their measured temperature.**



**Figure 161. Simulated temperature distribution in the Columbia River. The monitors are color coded to their measured temperature.**

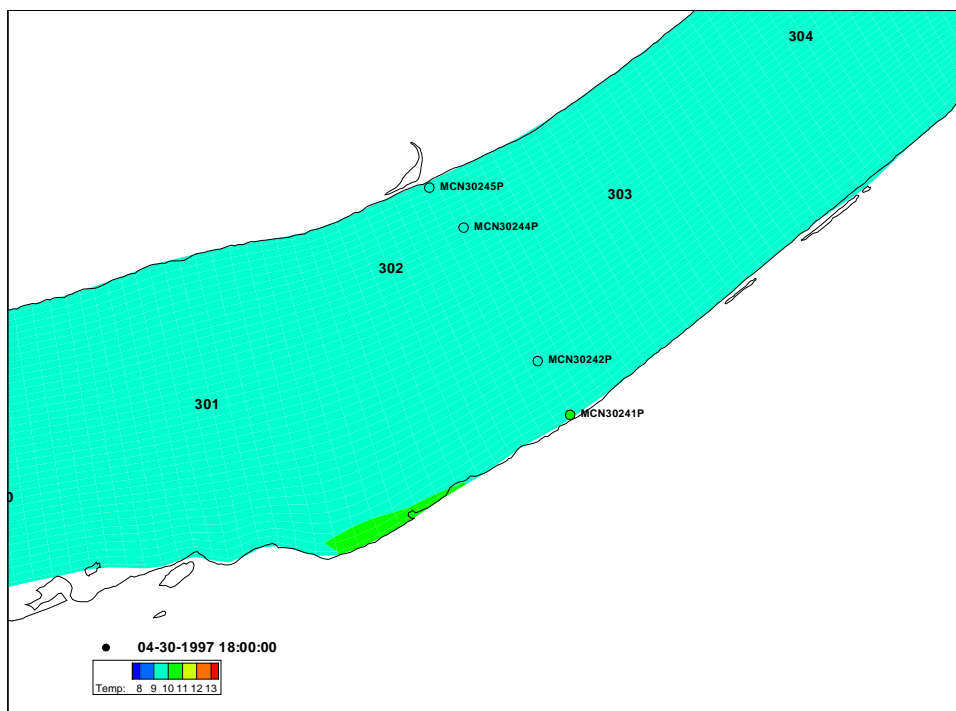


**Figure 162. Simulated temperature distribution at the confluence of the Columbia and Snake Rivers. The monitors are color coded to their measured temperature.**

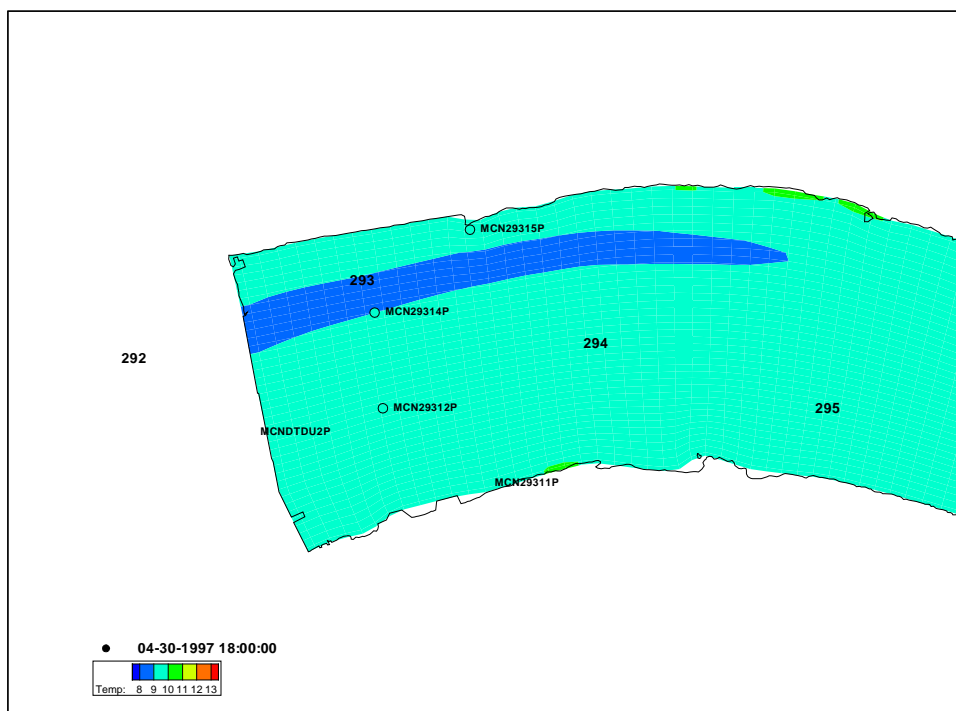


**Figure 163. Simulated temperature distribution in the Columbia River. The monitors are color coded to their measured temperature.**





**Figure 164. Simulated temperature distribution in the Columbia River. The monitors are color coded to their measured temperature.**



**Figure 165. Simulated temperature distribution in the Columbia River. The monitors are color coded to their measured temperature.**

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#### ***1.4.4 Discussion***

- Agreement with total dissolved gas concentrations are generally within 1.5 mg/l which is approximately 5% saturation
- Agreement with temperature are generally within 1 degree
- Degassing may help the situation at Wallula gap and beyond

- Application of the FINS Fish Exposure Model to McNary Pool

### 1.5 FINS Test Simulation

A series of example runs were executed using FINS based on hydrodynamic conditions as modeled for the time plane for 07-08-1996 1200. Using the constant set of hydrodynamics and water quality output fish migration was then simulated for a 24-hour period starting at 07-08-1996 1200 hrs.

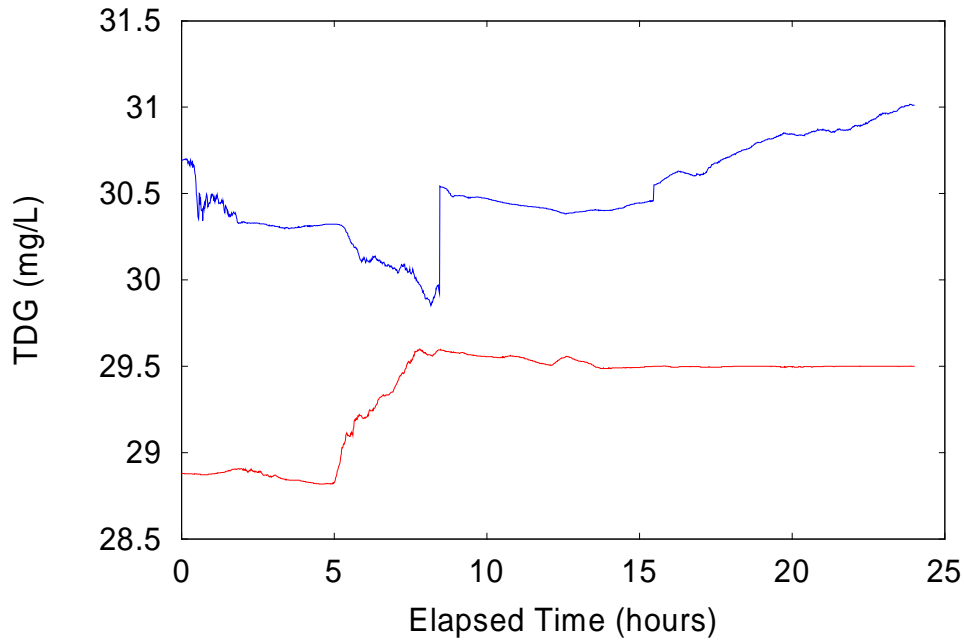
Twenty-five (25) simulated fish particles were released at a point corresponding to the center of the channel in the tailrace of Ice Harbor Dam. The small number of particles was simulated to facilitate graphical presentation of particle locations -- particles would be indistinguishable if a larger number of particles were simulated. However, the model is computationally capable of simulating much greater numbers of particles. The model runs used a time step of 50 seconds, and wrote simulated fish exposure logs to file every 60 minutes.

Migration processes simulated included:

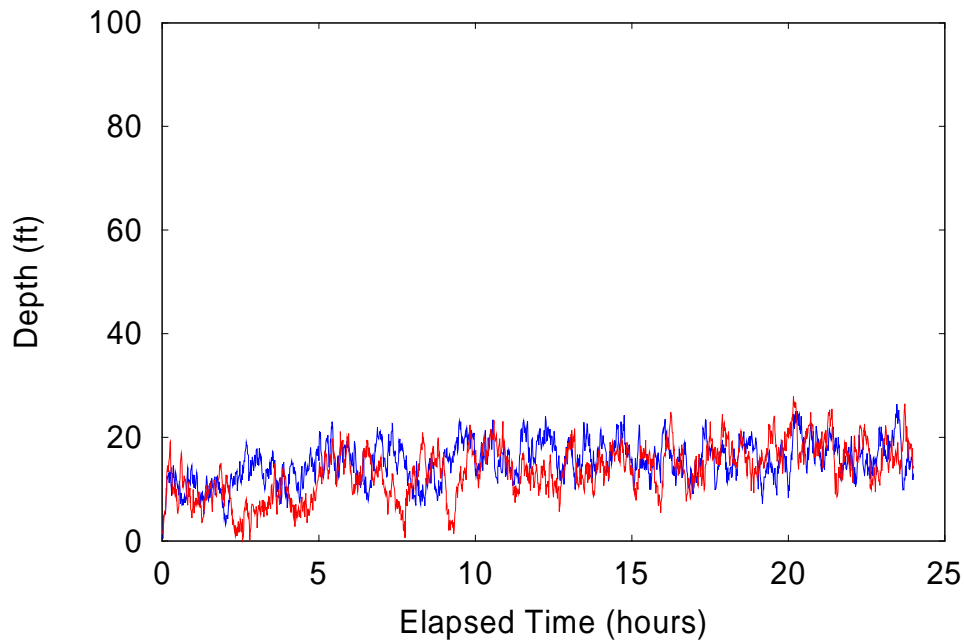
- Advection (with local flow velocities)
- Dispersion ( $D = \alpha V$  where  $D$  is dispersion coefficient,  $\alpha$  is "dispersivity" and  $V$  is local velocity magnitude.  $\alpha$  is given in terms of its longitudinal and transverse tensor components, which were specified for this run as 0.25 feet and 0.025 feet, respectively.)
- Vertical movement: The following were tested
  1. Combined random vertical velocity (mean = 0.0 ft/sec; variance = 0.001) and linear preference model (preferred depth = 16.0 feet; preference coefficient = 0.002)
  2. Random vertical velocity (mean = 0.0 ft/sec; variance = 0.001) only
  3. Random vertical velocity (mean = 0.0 ft/sec; variance = 0.005) only
  4. Combined random vertical velocity (mean = 0.0 ft/sec; variance = 0.001) and linear preference model (preferred depth = 2.0 feet; preference coefficient = 0.01)

Figure 166 shows the dissolved gas concentrations observed by two randomly-selected simulated fish. Figure 167 through Figure 170 show the depth history for the same two fish under the four different vertical movement cases above. While the depth does not affect the dissolved gas concentration observed by the fish (because the hydrodynamic model is 2D, vertically-averaged), the effect of these concentrations is strongly impacted by fish depth through the pressure depth-compensation. Figure 171 through Figure 175 show the fish distribution in the river at selected times after their release from Ice harbor Dam.

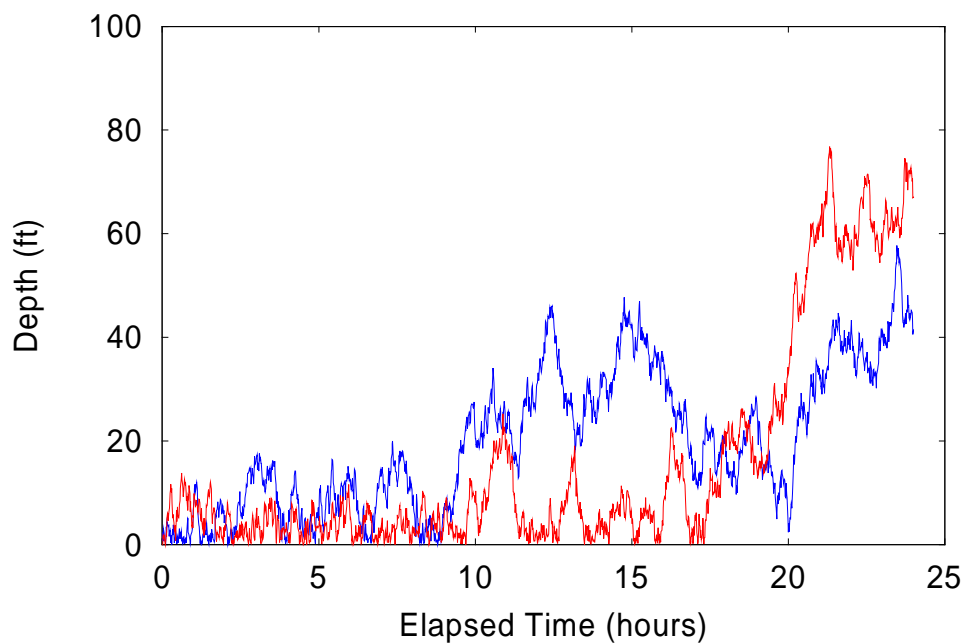
Dissolved gas and depth history files were provided to Dr. Larry Fidler for all 25 fish for each of cases 2 and 4 above.



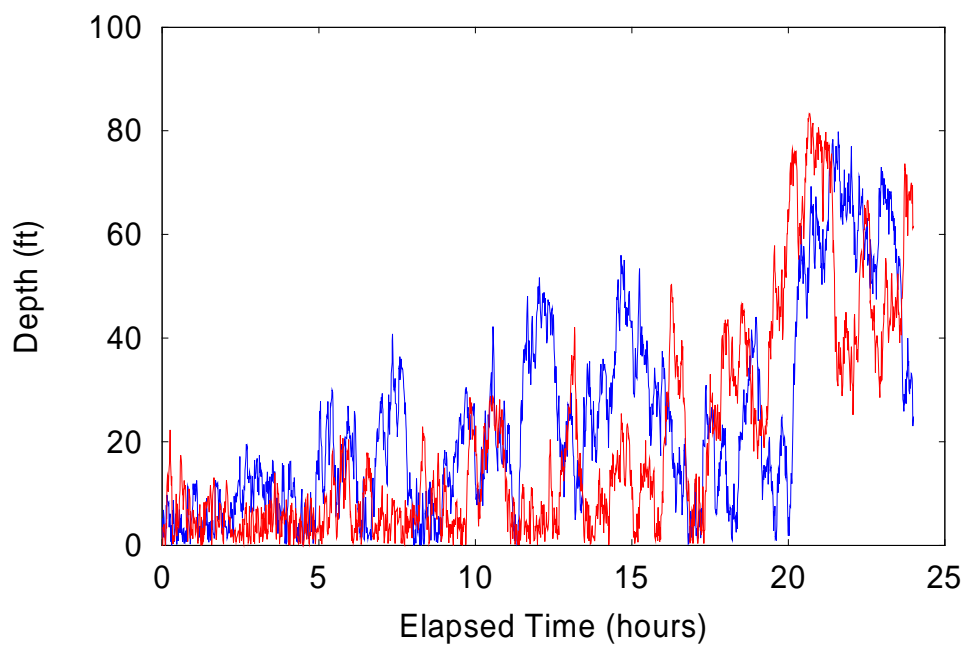
**Figure 166. Dissolved gas concentration exposure logs for 2 randomly selected fish.**



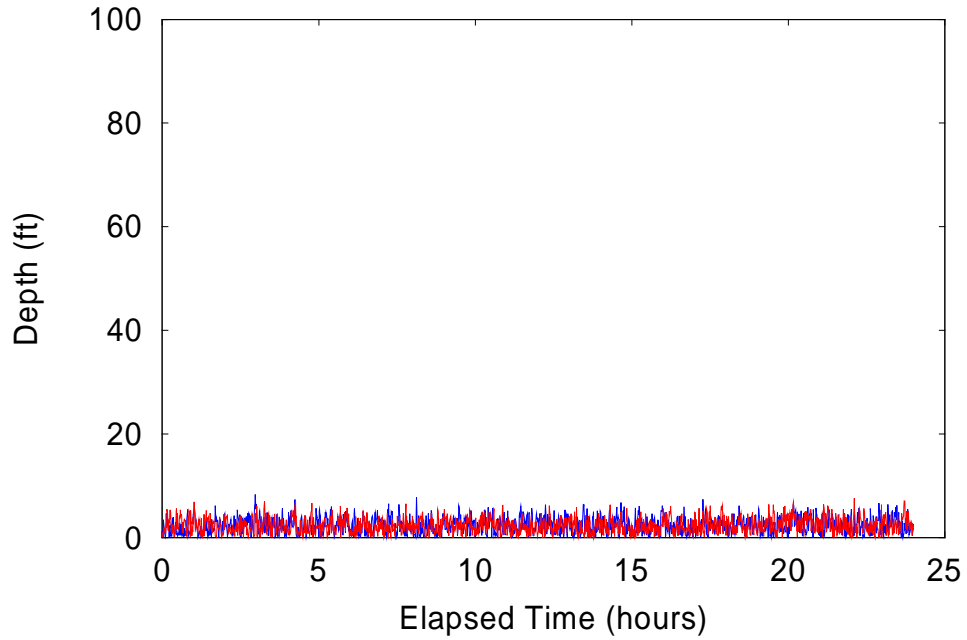
**Figure 167. Depth-histories for 2 fish using a random vertical velocity only (mean = 0.0 ft/s, variance = 0.001) and a depth-preference of 16 feet.**



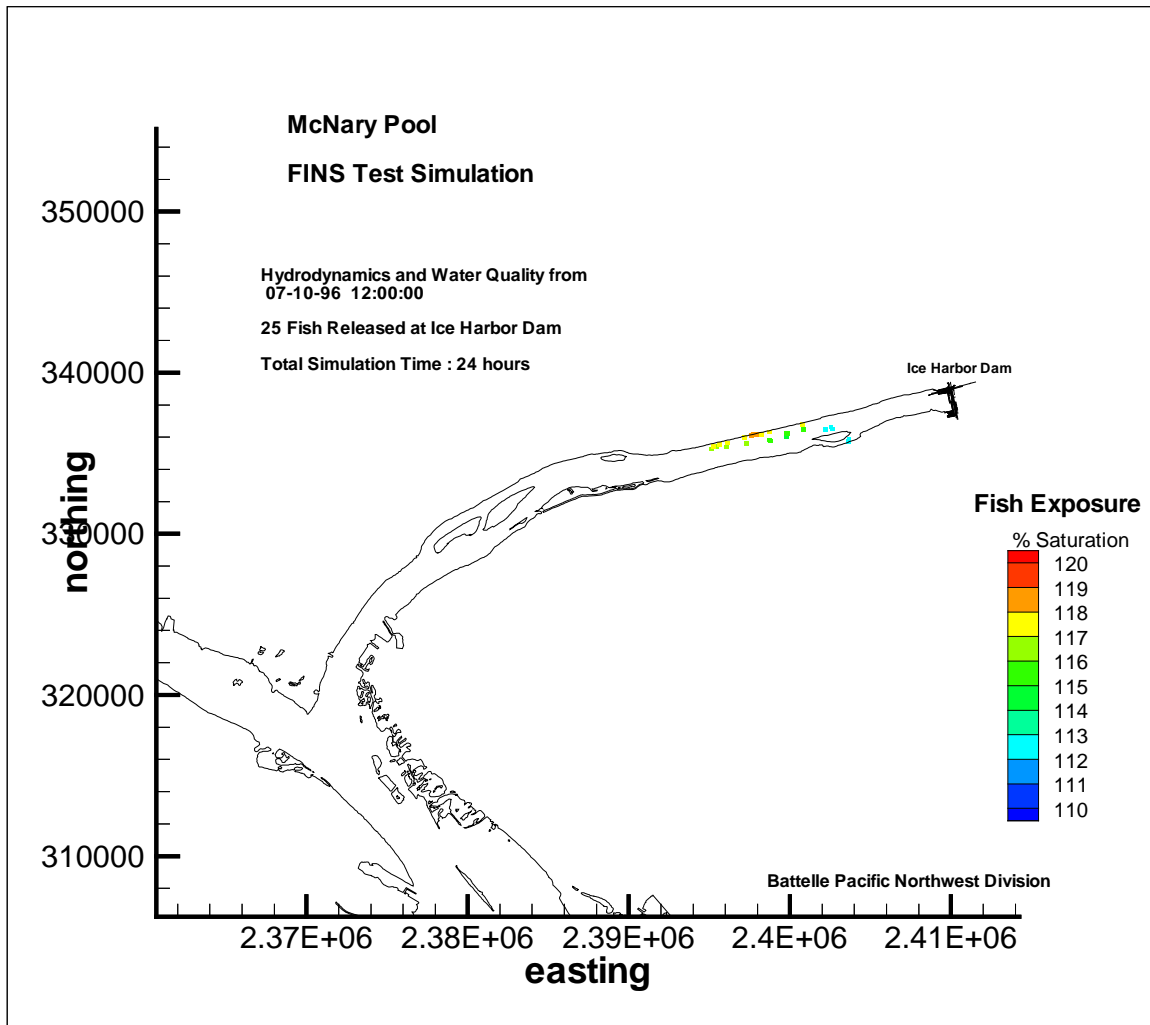
**Figure 168. Depth-histories for 2 fish using a random vertical velocity only (mean = 0.0 ft/s, variance = 0.001)**



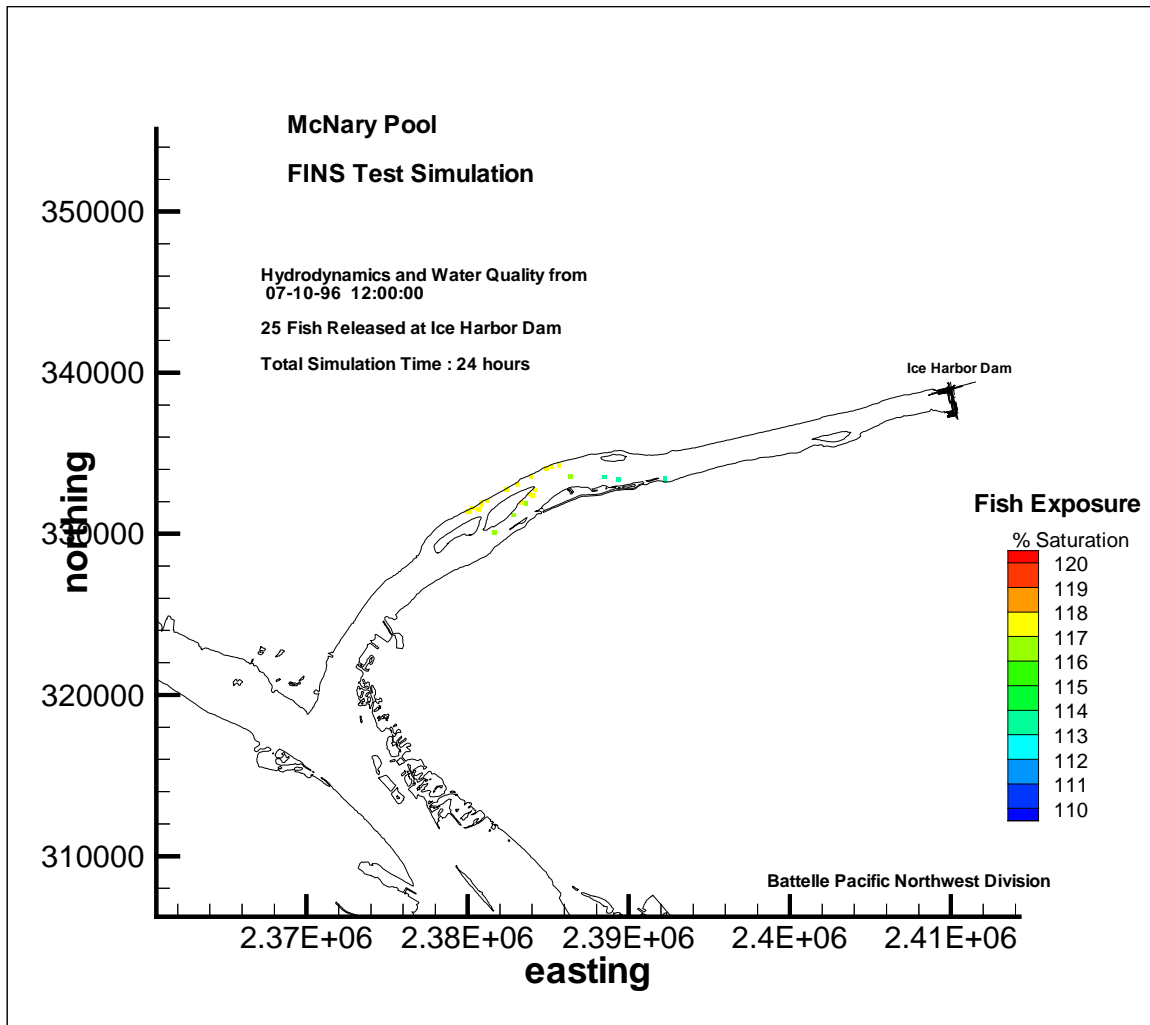
**Figure 169. Depth-histories for 2 fish using a random vertical velocity only only (mean = 0.0 ft/s, variance = 0.005)**



**Figure 170. Depth-histories for 2 fish using a random vertical velocity only (mean = 0.0 ft/s, variance = 0.001) and a depth-preference of 2 feet.**

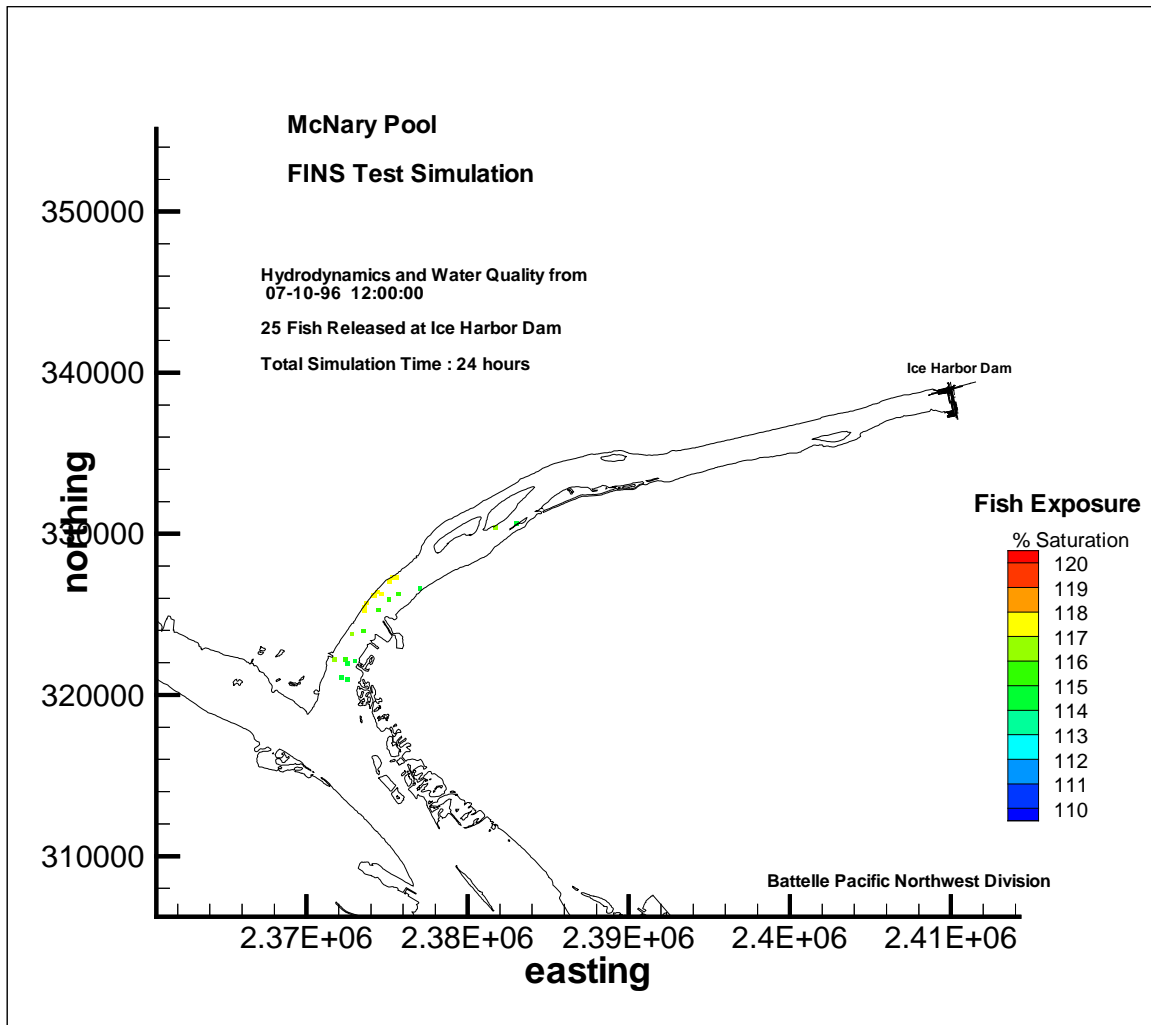


**Figure 171. Fish distribution 1 hour after release at Ice Harbor Dam. The fish particles are colored according to the level of dissolved gas exposure at that location.**

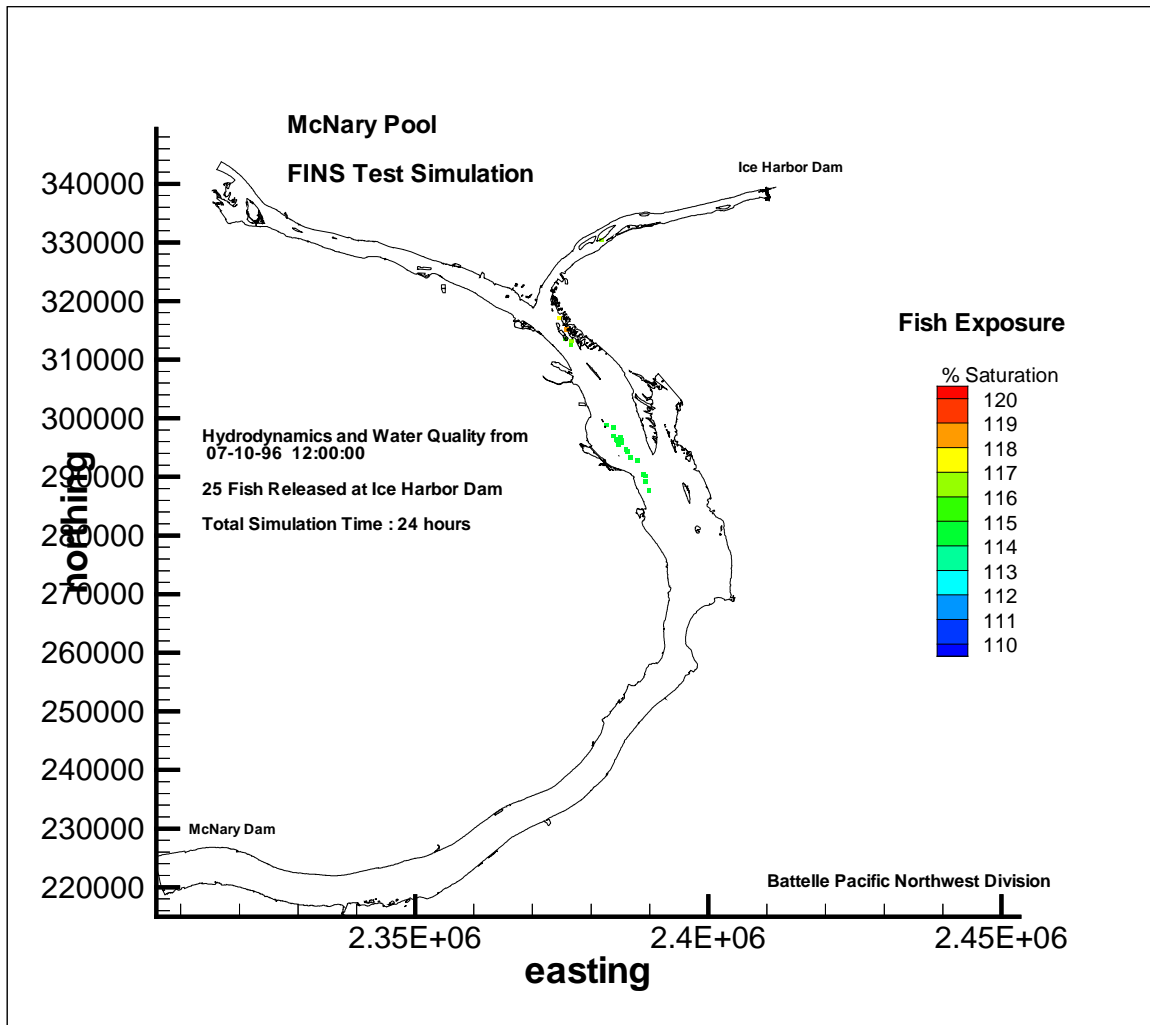


**Figure 172. Fish distribution 3 hours after release at Ice Harbor Dam. The fish particles are colored according to the level of dissolved gas exposure at that location.**

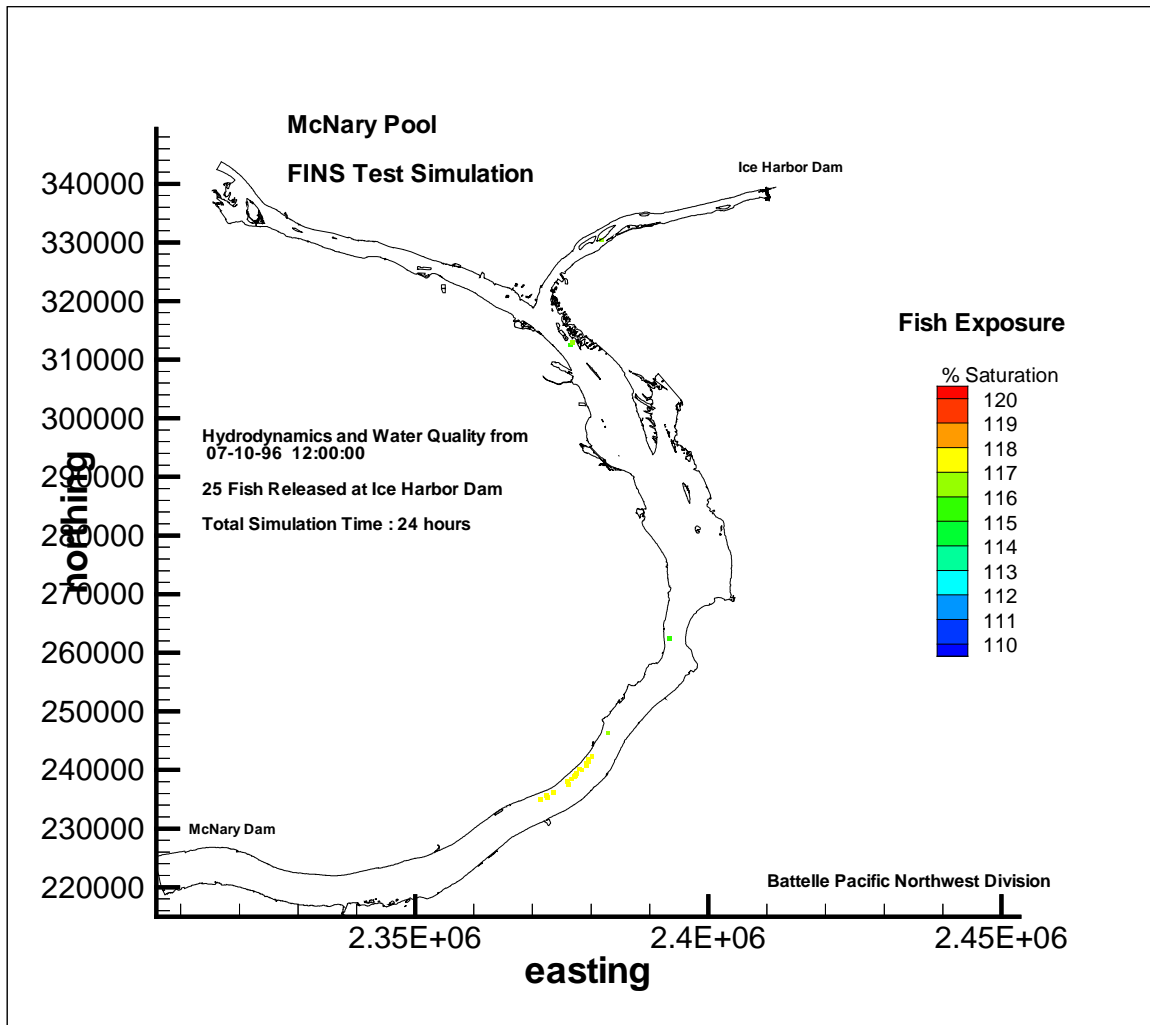




**Figure 173. Fish distribution 6 hours after release at Ice Harbor Dam. The fish particles are colored according to the level of dissolved gas exposure at that location.**



**Figure 174. Fish distribution 12 hours after release at Ice Harbor Dam. The fish particles are colored according to the level of dissolved gas exposure at that location.**



**Figure 175. Fish distribution 24 hours after release at Ice Harbor Dam. The fish particles are colored according to the level of dissolved gas exposure at that location.**

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## 2 References

Richmond, M.C., W.A. Perkins, and T.D. Scheibe. 1998. *Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 1: Summary and Model Formulation*. Draft Final Report submitted to U.S. Army Corps of Engineers, Walla Walla District. Battelle Pacific Northwest Division, Richland, Washington.

Schneider, M.L., and S.C. Wilhelms, 1997. *Total Dissolved Gas Production at Spillways on the Snake and Lower Columbia Rivers*. Memorandum for Record, CEWES-HS-L, U.S. Army Corps of Engineers, Available (limited access): [limnos.wes.army.mil](http://limnos.wes.army.mil)  
Directory: /data3/dgas/Documents/reports/ File: dgasprod.exe.

Steinbrenner J.P., and J.R. Chawner, 1995. *The GRIDGEN Version 9 Multiple Block Grid Generation Software*. MDA Engineering, Inc., Arlington, Texas.

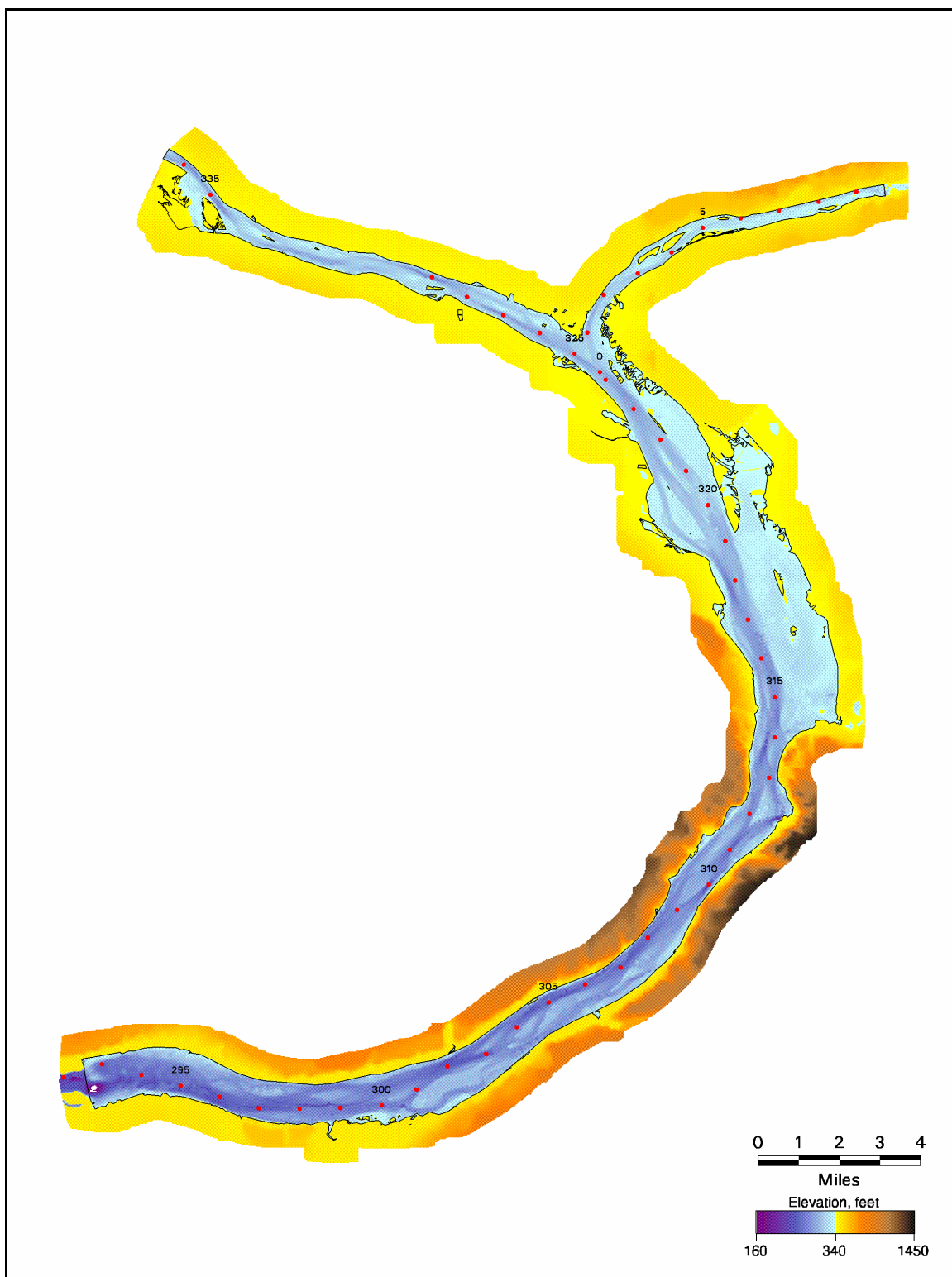
## Appendix A. McNary Pool Data Sources

### A.1 Bathymetry

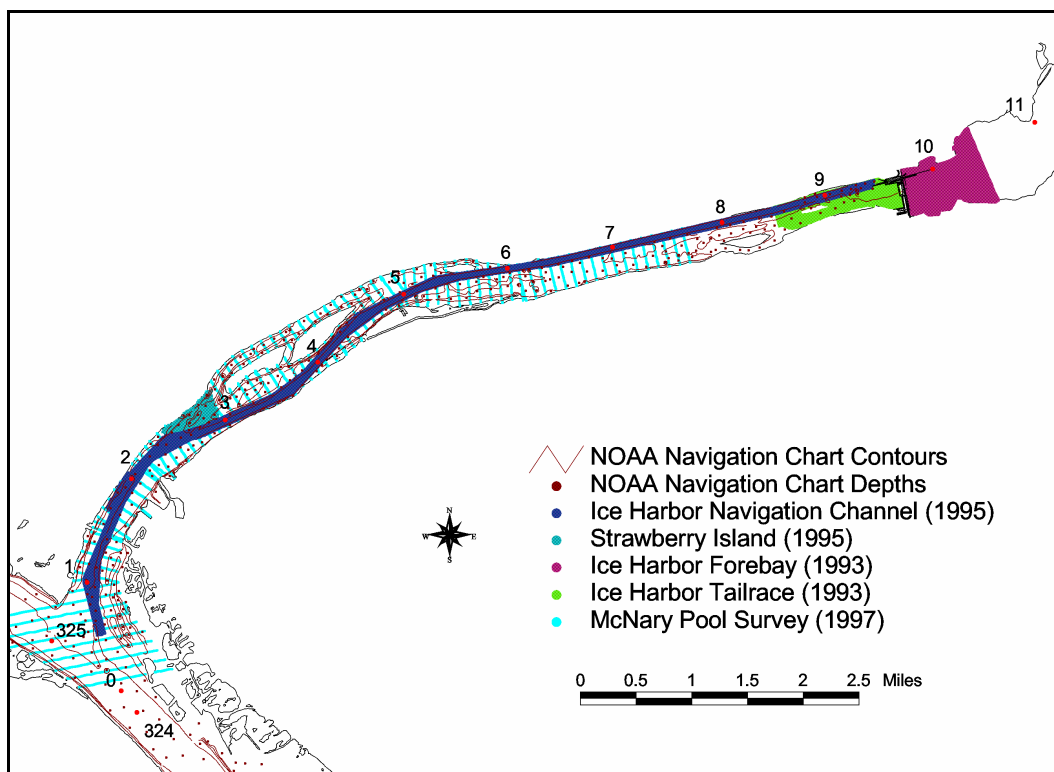
Three-dimensional representations of the river bottom and surrounding shore were used to generate bottom elevations for the hydrodynamic model. Bathymetric data for the Columbia and Snake Rivers was gathered from the various sources shown in Table 80. Using the Arc/Info® GIS software system, the data was converted to a consistent coordinate system and datum, and combined to build a triangular irregular network (TIN), which represented the river bottom and shore as a three-dimensional surface. The surface for McNary pool is shown in Figure 176. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid.

**Table 80. Snake and Columbia River bathymetry data sets used to create the McNary pool bathymetric surface. The listed Figure number refers to the map which shows the survey location(s).**

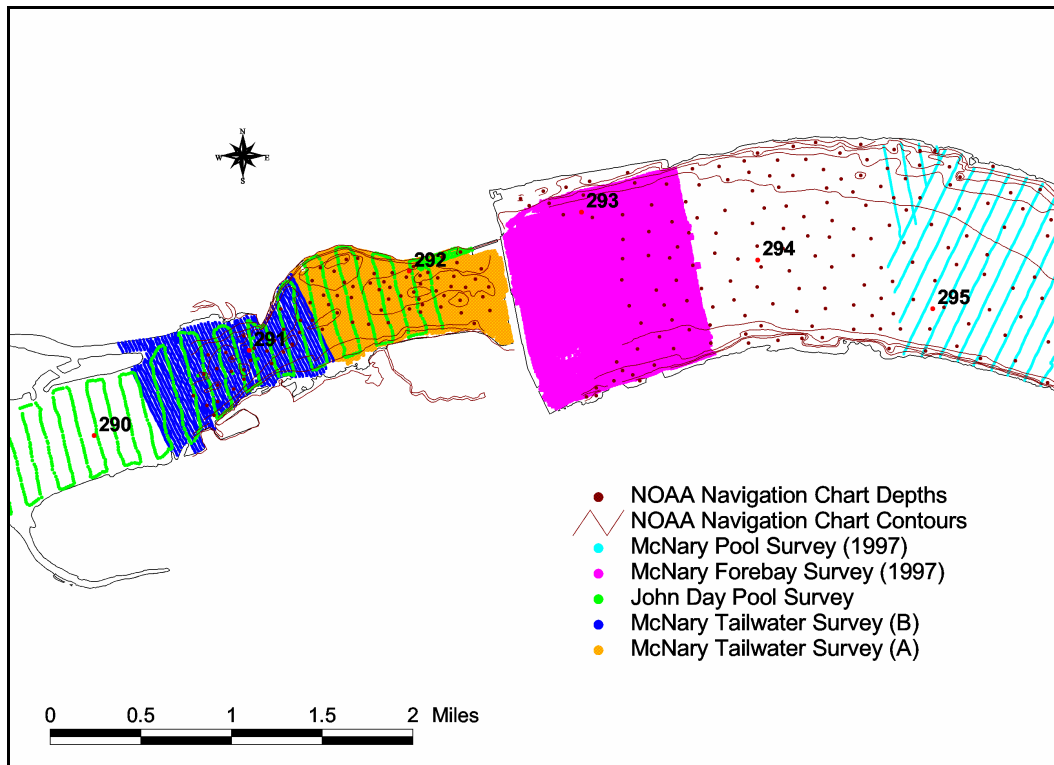
Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
Ice Harbor Dam Navigation Channel (Figure 177)	Julie Davin (Walla Walla)	1995	0.0	9.5
Strawberry Island (Figure 177)	Julie Davin (Walla Walla)	1995	2.5	3.0
Ice Harbor Dam Tailrace (Figure 177)	Julie Davin (Walla Walla)	1993	8.5	9.7
Ice Harbor Dam Forebay (Figure 177)	Julie Davin (Walla Walla)	1993	9.7	10.4
McNary Pool Survey, (Columbia River, Figure 178)	Gary Slack (Walla Walla)	1997	293.5	335.5
McNary Pool Survey (Snake River, Figure 177)	Gary Slack (Walla Walla)	1997	0.0	7.5
McNary Dam Tailrace Surveys (Figure 178)	Gregg Bertrand (Portland)	unknown	290.3	292.5
McNary Dam Forebay (Figure 178)	Gary Slack (Walla Walla)	1997	292.5	293.5
John Day Pool Survey (Figure 178)	George Kalli (Portland)	unknown	216.5	292.5
NOAA Navigation Charts (Figure 177 and Figure 178)	Battelle	unknown	291.0	329.0



**Figure 176. Color representation of the McNary pool bathymetric surface.**



**Figure 177. Bathymetric data near Ice Harbor dam.**



**Figure 178. Bathymetric data near McNary dam.**

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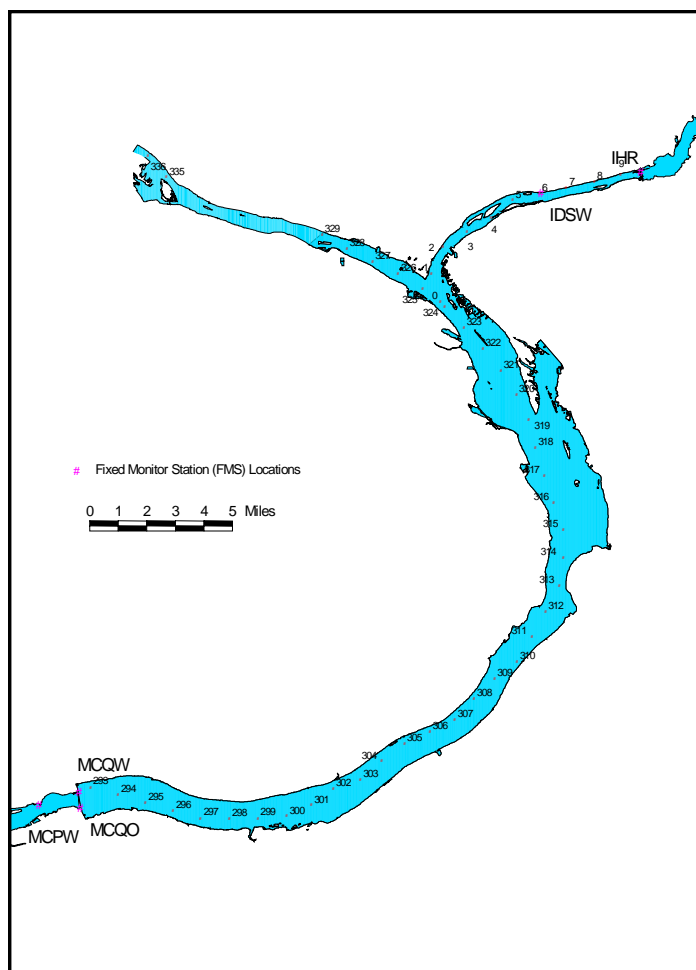
## ***A.2 Calibration/Verification Data Sources***

### ***A.2.1 Dissolved Gas Measurements***

Dissolved gas measurements were available from two sources: fixed monitors and dissolved gas pool studies. Fixed monitor stations (FMS) in the McNary pool area are shown in Figure 179. The water quality data recorded by the FMS included total dissolved gas (TDG) pressure, barometric pressure, and temperature, and was obtained from the DGAS team ftp server `limnos.wes.army.mil`, in the file `/data3/dgas/database/FMS_data/FMS_data.zip`, dated April 8, 1998.

Three dissolved gas pool studies have been performed in McNary Pool to date. The study dates are shown in Table 81 and graphically in Figure 180. During these studies water temperature and TDG pressures were measured for a short period of time at several locations within McNary pool. These periods were used for model calibration and verification and are discussed individually below. The water quality data gathered during these studies was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/field_data/field_data.zip`, dated April 20, 1998.

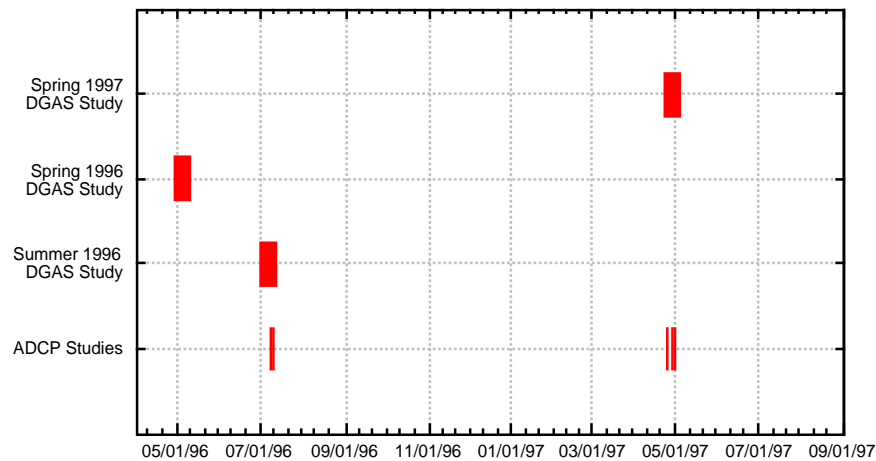




**Figure 179. FMS locations in and around McNary pool.**

**Table 81. Dates of dissolved gas field studies in McNary pool.**

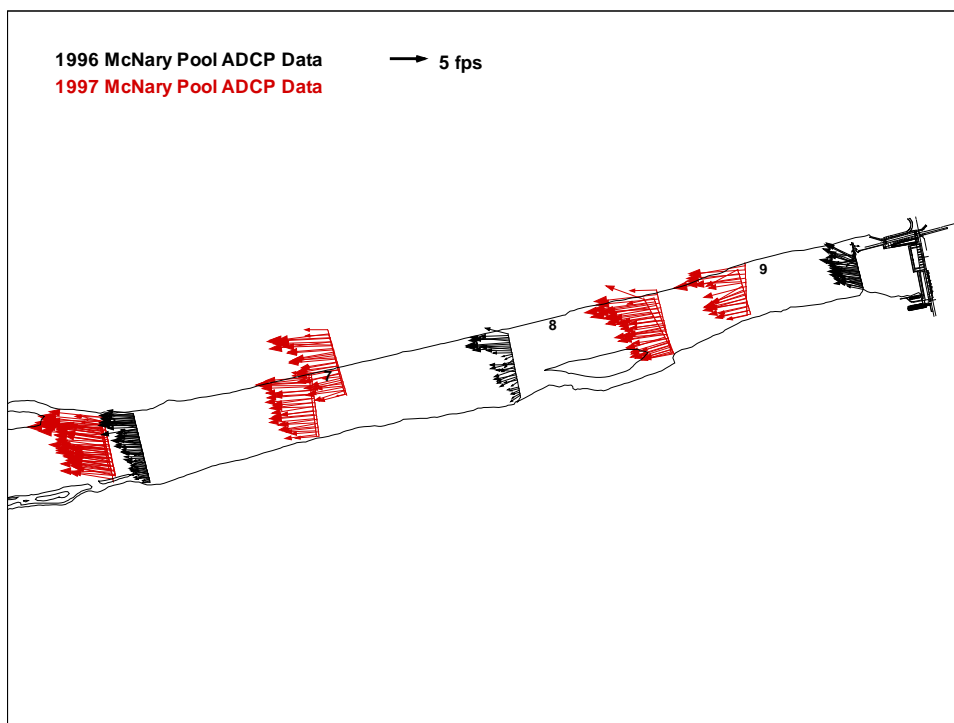
STUDY SET	Start	End
MCN SPR 96	4/29/96 4:52:00 PM	5/10/96 7:32:00 PM
MCN SUM 96	7/1/96 10:00:00 AM	7/12/96 4:15:00 PM
IHR MCN SPR 97	4/22/97 12:20:00 PM	5/3/97 11:00:00 AM



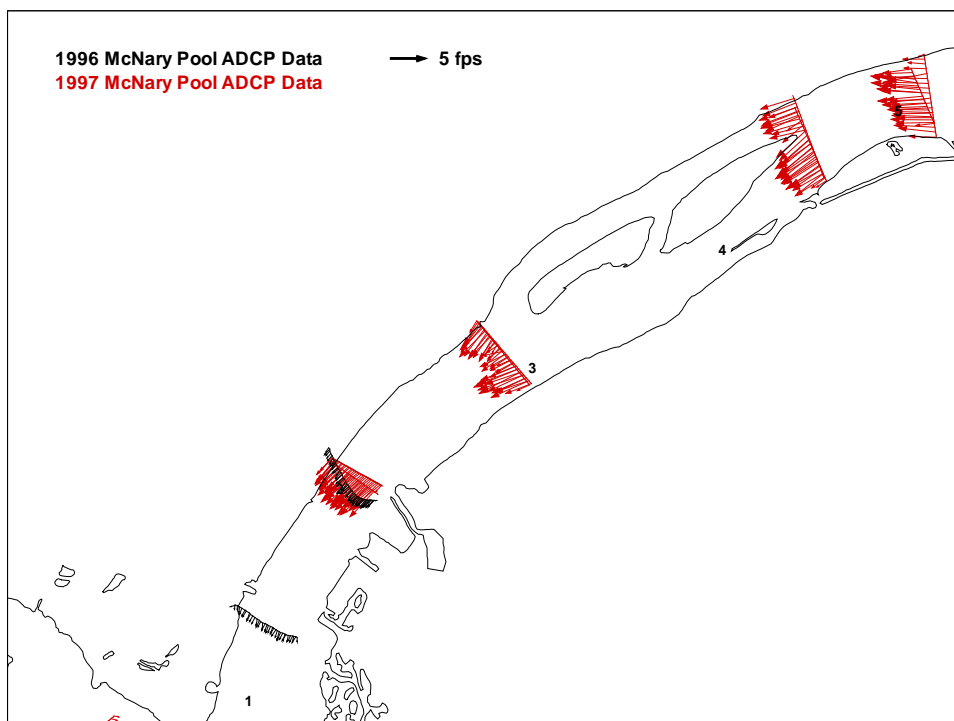
**Figure 180. Dates and duration of dissolved gas and ADCP velocity measurement studies in McNary Pool.**

#### *A.2.2 ADCP Velocity Measurements*

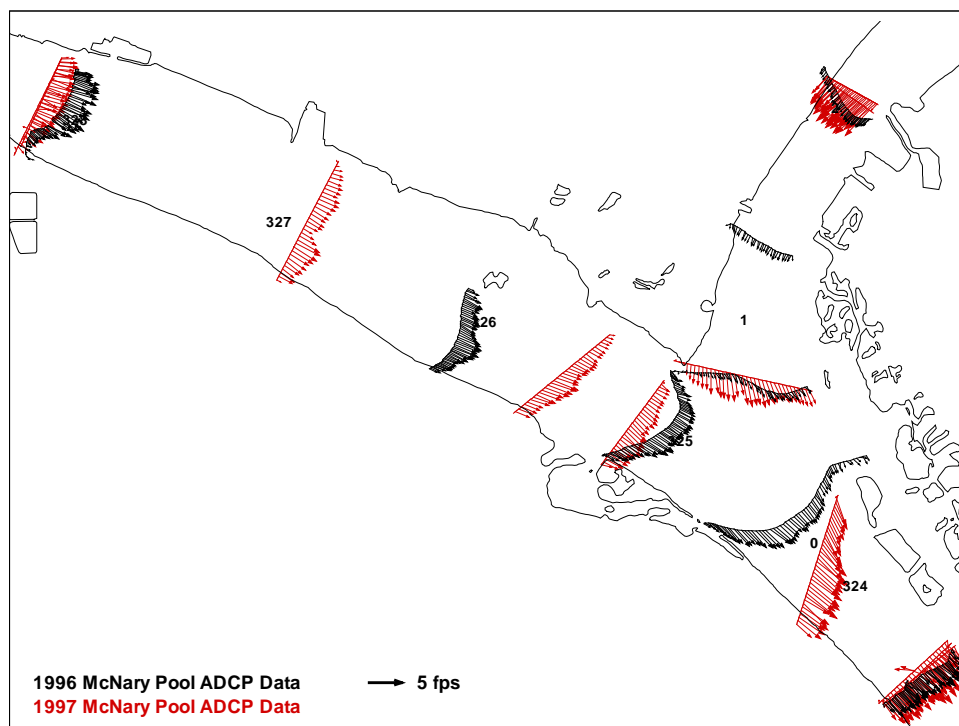
As shown in Figure 180, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Summer 1996 and Spring 1997. The data was obtained from the DGAS team FTP server, [limnos.wes.army.mil](http://limnos.wes.army.mil), in the files `/data3/dgas/database/ADCP data/96ADCP.zip` and `/data3/dgas/database/ADCP data/97ADCP.zip`, dated April 10, 1998 and April 30, 1998, respectively. Figure 181 through Figure 188 show the measurements made as small arrows. The 1997 measurements were thinned for clarity in those figures: only one in three arrows were drawn.



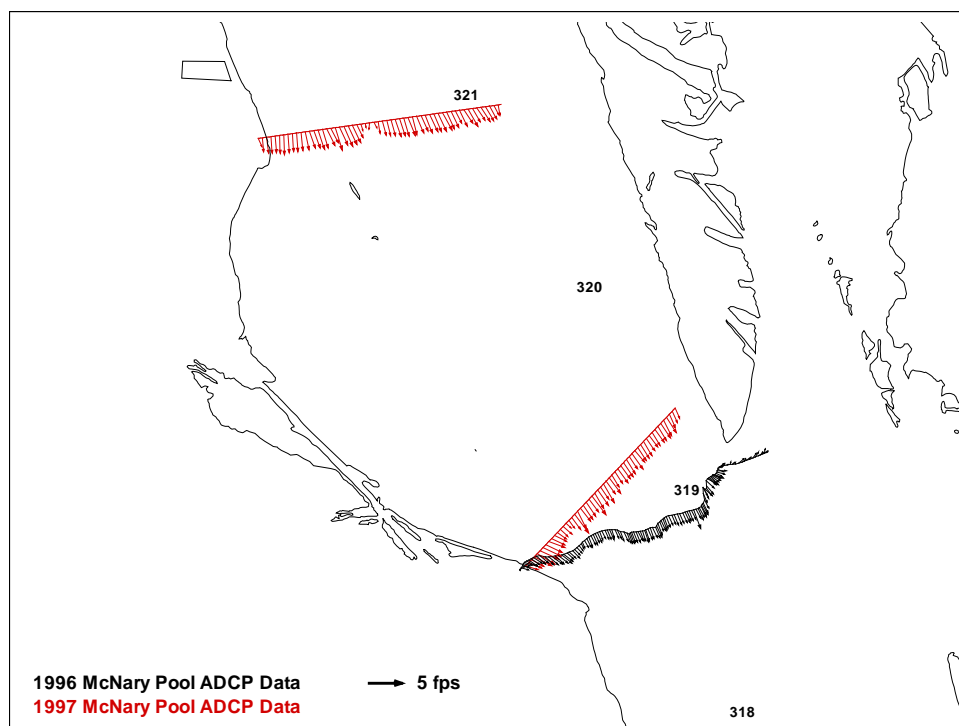
**Figure 181. McNary pool ADCP velocity measurements near Ice Harbor dam.**



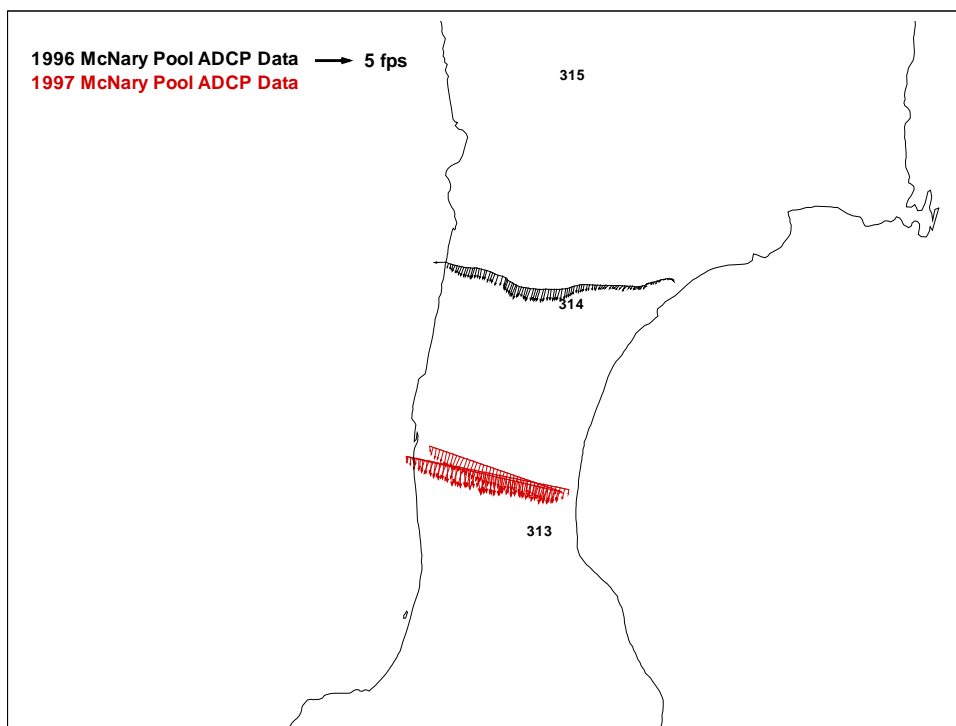
**Figure 182. McNary pool ADCP velocity measurements near Strawberry Island.**



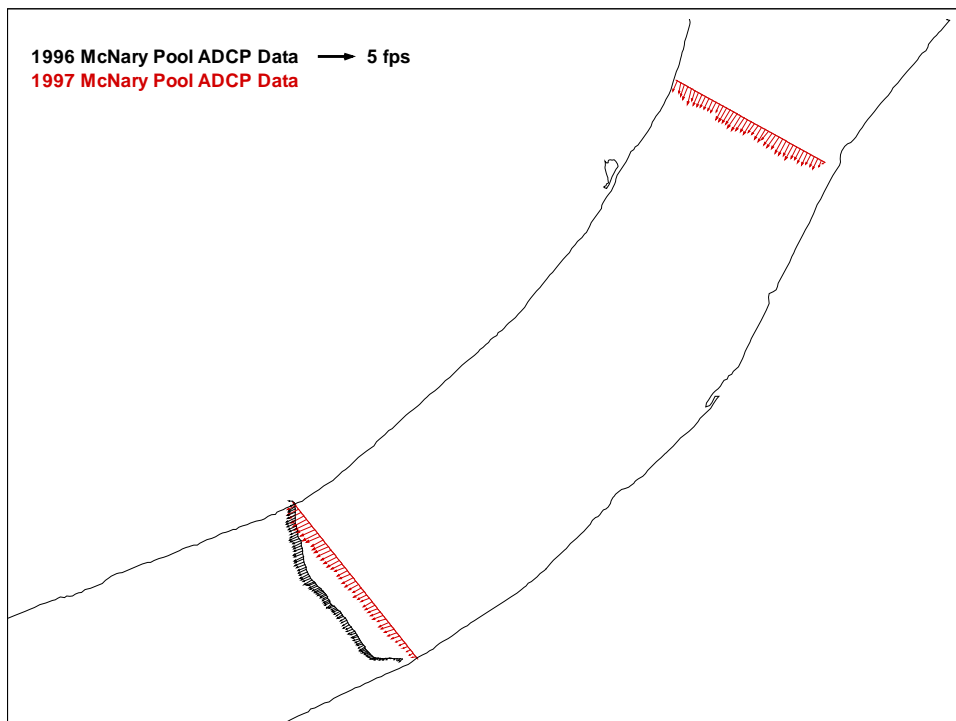
**Figure 183. McNary pool ADCP velocity measurements near the Snake River mouth.**



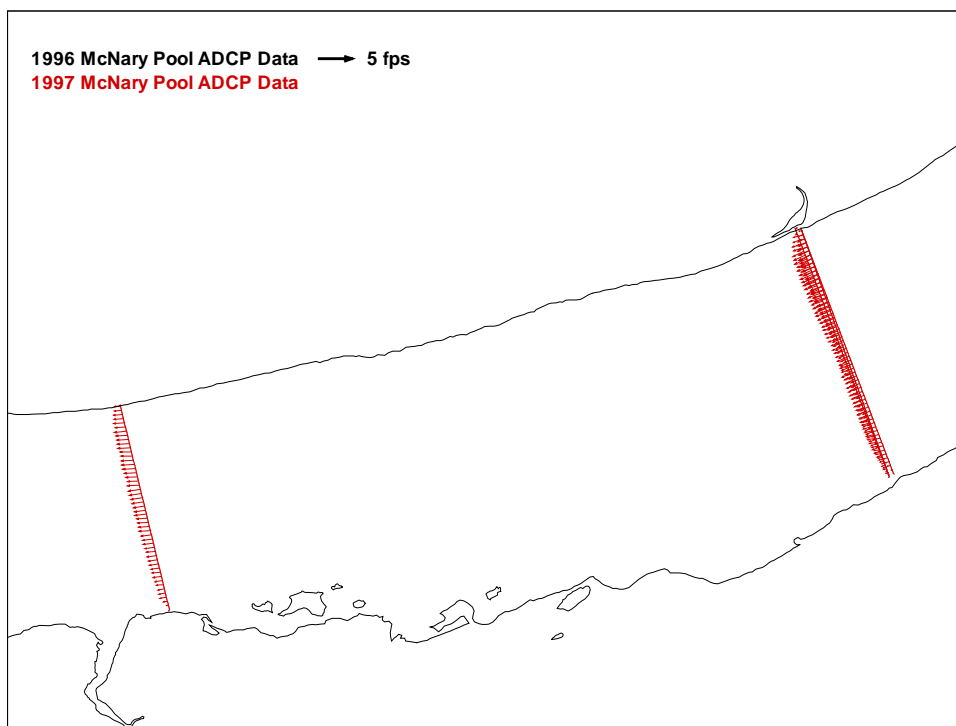
**Figure 184. McNary pool ADCP velocity measurements near Burbank Slough.**



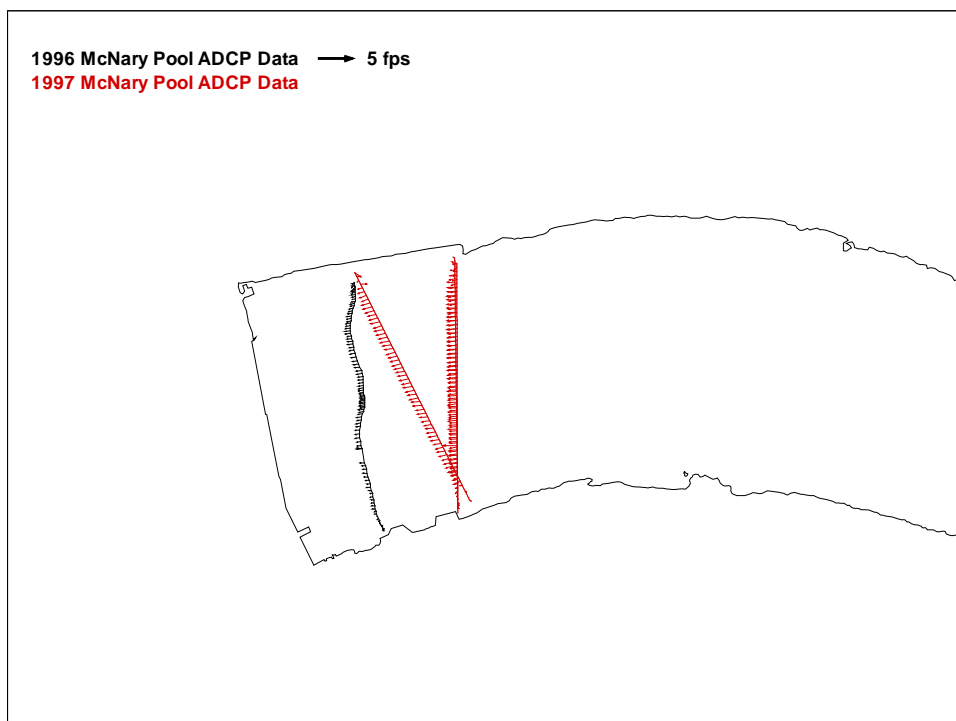
**Figure 185. McNary pool ADCP velocity measurements near Wallula Gap.**



**Figure 186. McNary pool ADCP velocity measurements below Wallula Gap.**



**Figure 187. McNary pool ADCP velocity measurements near Hat Rock State Park.**



**Figure 188. McNary pool ADCP velocity measurements near McNary dam.**

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### *A.2.3 Dam Operations Data*

Dam operations data was used to establish model boundary conditions. Hourly CHROMS data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/ops_data/ops_data.zip`, dated April 8, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

### *A.2.4 Weather Data*

Weather data was obtained from two DGAS team databases: one containing data from National Weather Service (NWS) stations, the other from WeatherPak instrumentation used for short periods during the pool studies. Both NWS and WeatherPak data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/weather_data/weather_data.zip`, dated April 8, 1998.

## Appendix B. Spring 1996 McNary Pool Study

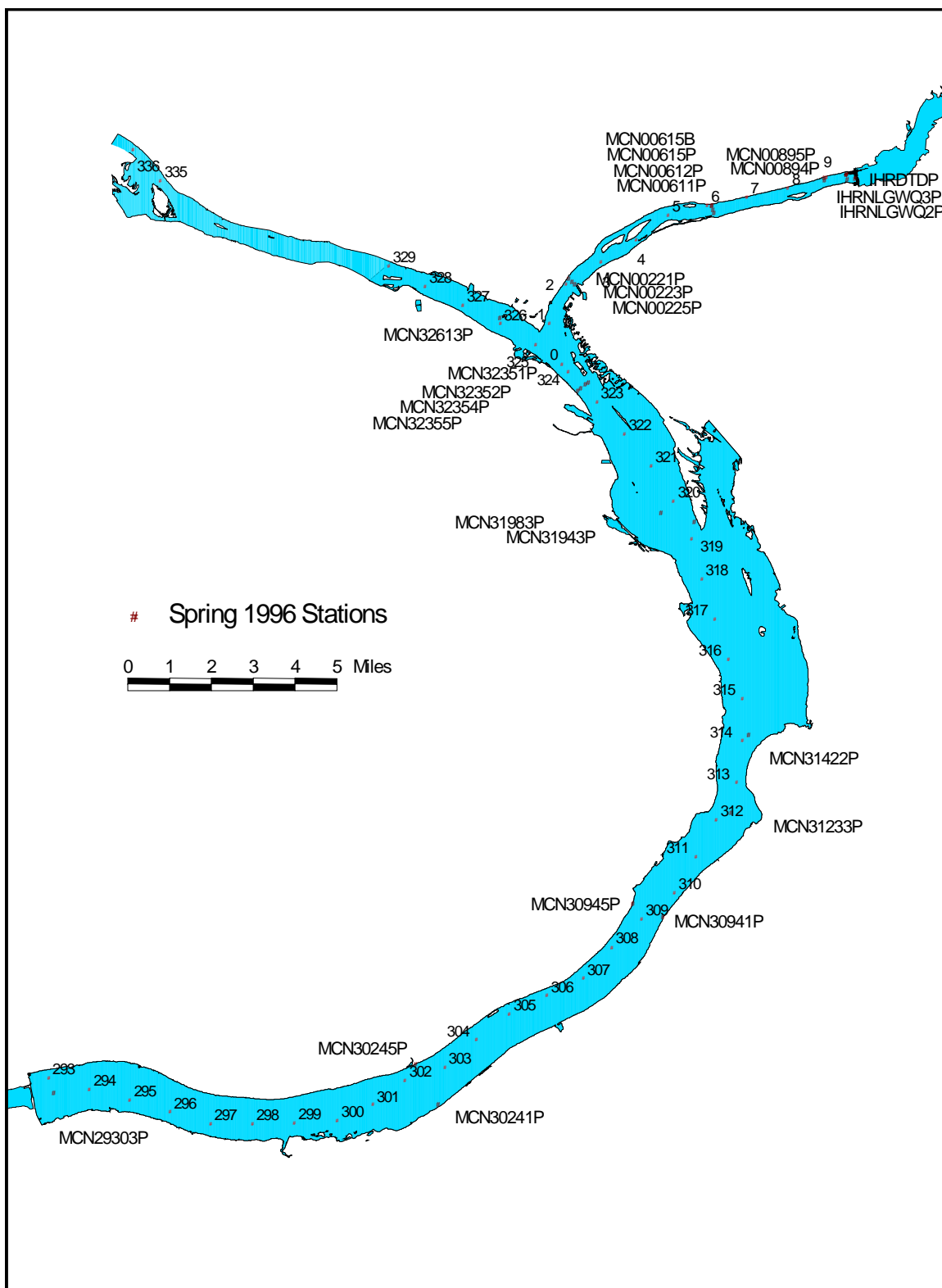
### B.1 DGAS Data

The Spring 1996 McNary pool dissolved gas study started on April 29 and ended on May 10. A total of 28 water quality monitors were used. These stations, and their records, are listed in Table 82. Station locations are shown in Figure 189.

**Table 82. Dissolved gas monitor stations, and their records, used during the Spring 1996 McNary pool study.**

STATION	Start	End	Records
MCN00225P	4/29/96 4:52:00 PM	5/9/96 1:52:00 PM	949
MCN00223P	4/29/96 5:25:00 PM	5/9/96 2:10:00 PM	947
MCN00221P	4/29/96 5:40:00 PM	5/9/96 1:55:00 PM	946
MCN32613P	4/29/96 6:19:00 PM	5/10/96 5:19:00 AM	1004
MCN00894P	4/29/96 7:27:00 PM	5/9/96 5:42:00 PM	954
IHRDTP	5/1/96 12:21:00 PM	5/9/96 5:03:00 PM	785
IHRNLGWQ3P	5/3/96 12:01:00 AM	5/9/96 5:01:00 PM	645
IHRNLGWQ4P	5/3/96 12:10:00 AM	5/9/96 4:40:00 PM	642
IHRNLGWQ5P	5/3/96 12:13:00 AM	5/9/96 3:43:00 PM	638
IHRNLGWQ2P	5/4/96 2:24:00 PM	5/9/96 5:39:00 PM	494
MCN00895P	5/4/96 3:07:00 PM	5/9/96 6:36:00 PM	489
MCN00615B	5/4/96 5:05:00 PM	5/9/96 7:18:00 PM	484
MCN32352P	5/4/96 5:50:00 PM	5/9/96 7:20:00 PM	486
MCN00611P	5/4/96 6:00:00 PM	5/9/96 7:45:00 PM	488
MCN32354P	5/4/96 6:08:00 PM	5/9/96 7:08:00 PM	485
MCN00615P	5/5/96 3:28:00 PM	5/10/96 6:58:00 PM	495
MCN32351P	5/5/96 5:47:00 PM	5/10/96 7:32:00 PM	488
MCN32355P	5/5/96 6:26:00 PM	5/10/96 6:56:00 PM	483
MCN00612P	5/5/96 6:29:00 PM	5/9/96 7:29:00 PM	389
MCN30941P	5/6/96 12:06:00 AM	5/10/96 3:36:00 PM	392
MCN30245P	5/6/96 11:33:00 AM	5/10/96 2:48:00 PM	398
MCN29303P	5/6/96 11:39:00 AM	5/10/96 1:39:00 PM	392
MCN30241P	5/6/96 11:57:00 AM	5/10/96 3:12:00 PM	398
MCN30945P	5/6/96 2:12:00 PM	5/10/96 3:57:00 PM	392
MCN31233P	5/6/96 3:42:00 PM	5/10/96 4:12:00 PM	387
MCN31422P	5/6/96 4:12:00 PM	5/10/96 4:42:00 PM	387
MCN31943P	5/6/96 4:47:00 PM	5/10/96 5:02:00 PM	386
MCN31983P	5/6/96 5:05:00 PM	5/10/96 5:20:00 PM	386





**Figure 189. Dissolved gas monitor locations during the Spring 1996 study.**

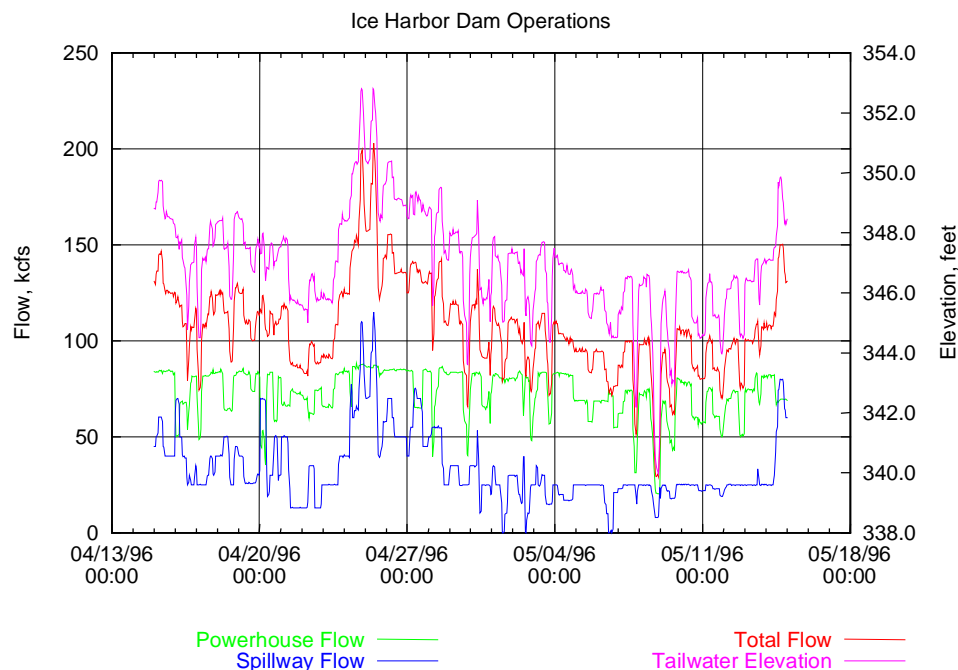
## B.2 Velocity Data

No velocity measurements were made during the Spring 1996 study.

## B.3 Ice Harbor Dam Boundary

### B.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Ice Harbor dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 190. These flows were uniformly distributed across the corresponding part of the model grid.



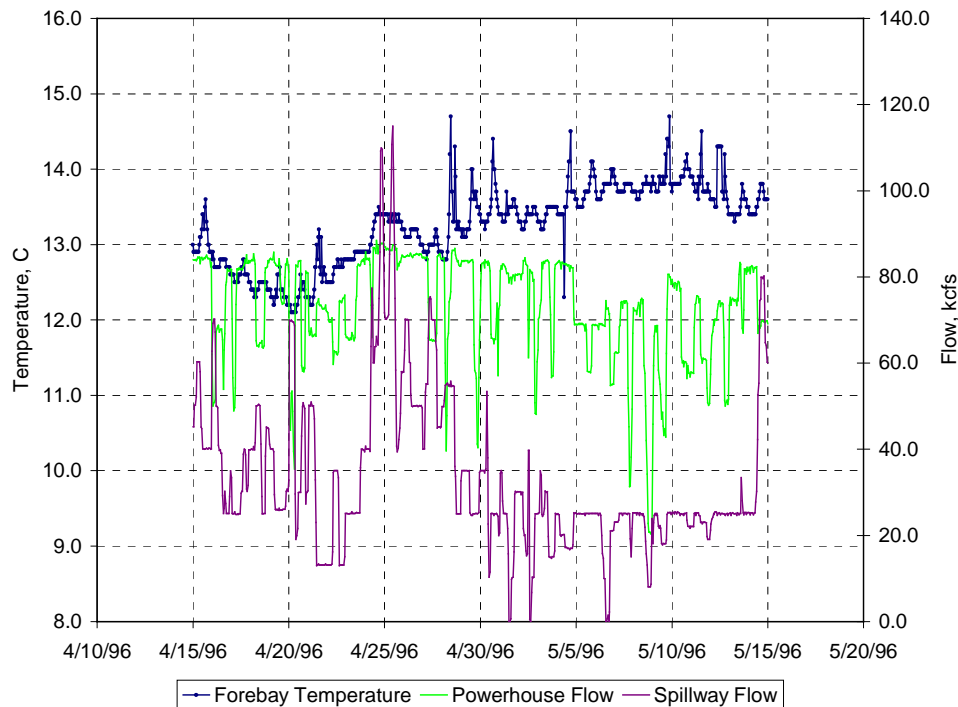
**Figure 190. Ice Harbor Dam operations during the Spring 1996 study.**

### B.3.2 Water Quality

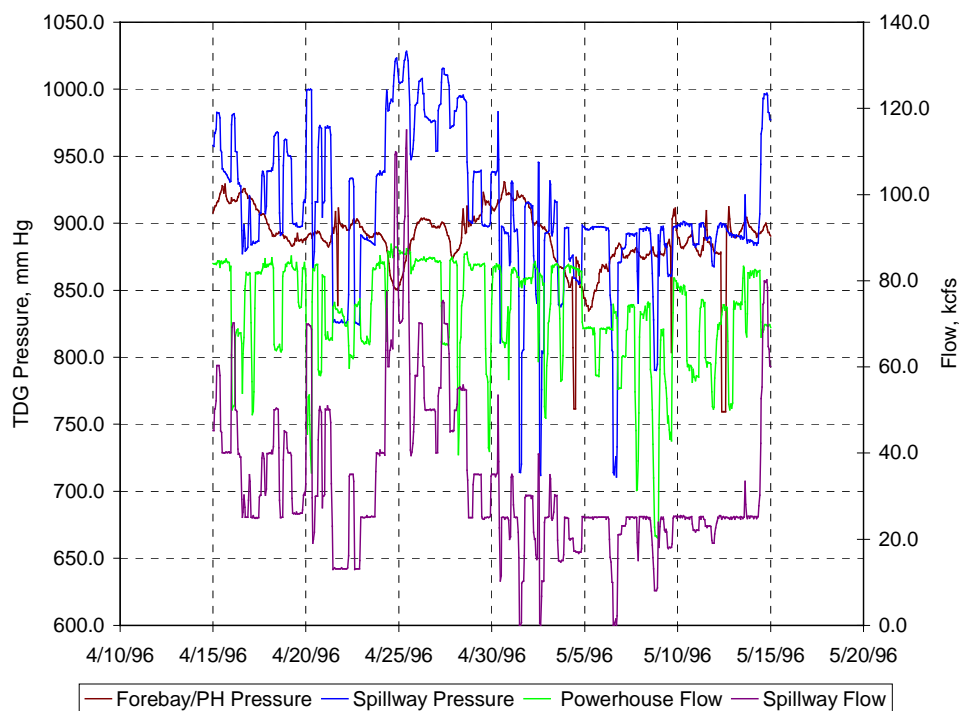
Initially, data from the fixed monitor located in the Ice Harbor forebay (station name "IHR") was used to establish water quality at the Ice Harbor boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 191) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 192) was used to compute TDG concentrations (Figure 193) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 192 and Figure 193, respectively) were estimated using the TDG sourcing function for Ice Harbor.

Ice Harbor dam model boundary temperature and dissolved gas concentrations were also established using the temporary pool study monitors. Five temporary monitors were

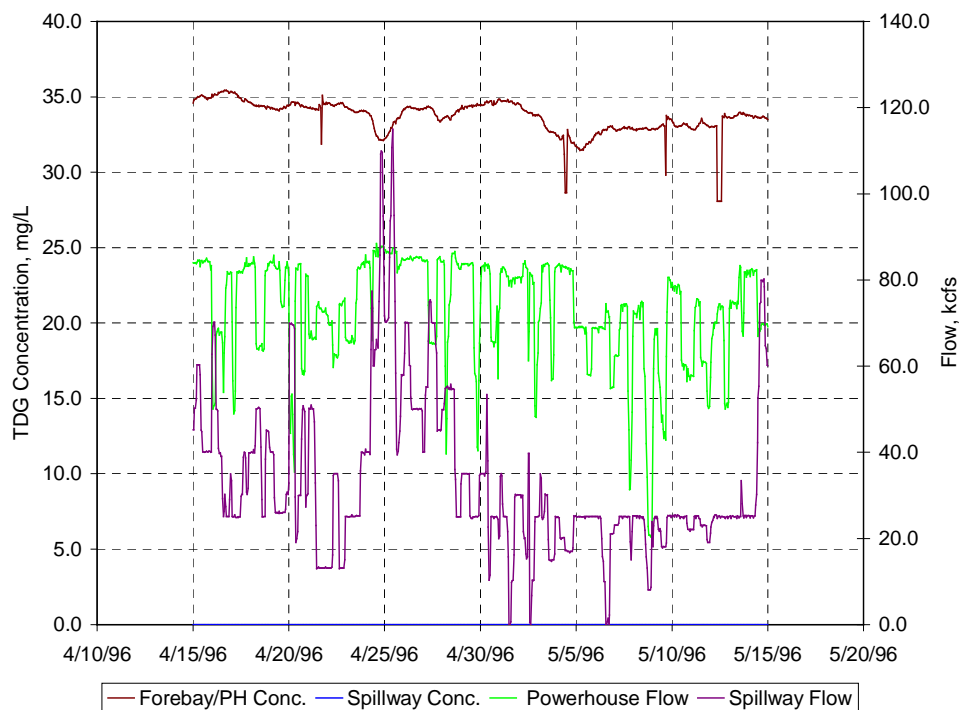
located in the Ice Harbor tailrace during Spring 1996 study period. Measured temperatures, measured TDG pressures and computed TDG concentrations from these stations are shown in Figure 194, Figure 195, and Figure 196, respectively. Water temperature measured at the draft tube monitor, station IHRDTDP was used for both spillway and power house flows. TDG pressures and temperatures measured at the IHRDTDP station were used to compute TDG concentrations for powerhouse flows. TDG pressures and temperatures measured at the IHRNLGWQ5P station were used to compute TDG concentrations used for flows in the north half of the spillway; The IHRNLGWQ4P station was used for south half of the spillway.



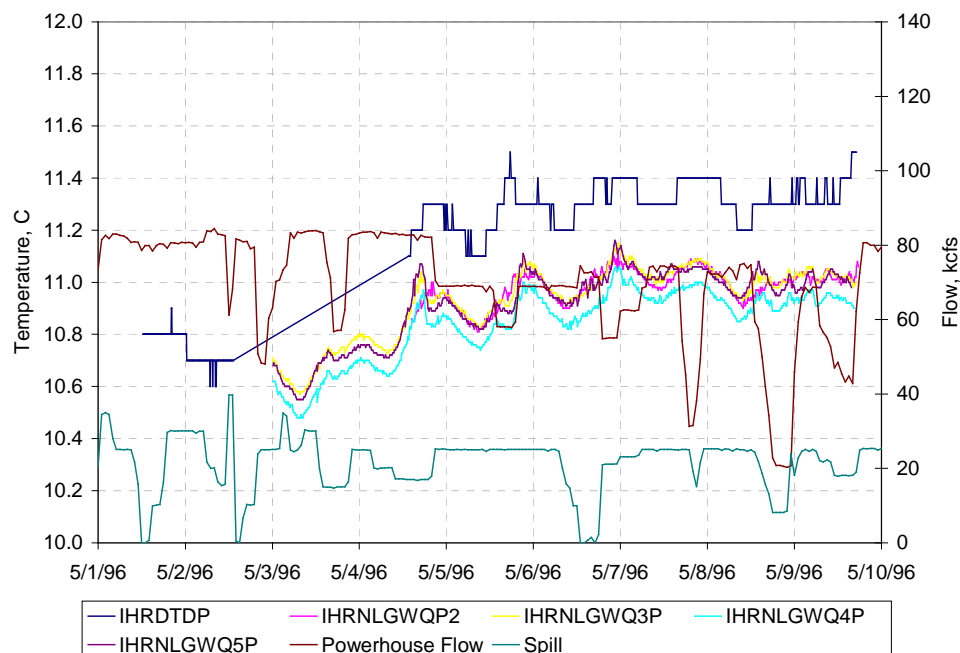
**Figure 191. Water temperature measured by the fixed monitor at Ice Harbor dam during the Spring 1996 study.**



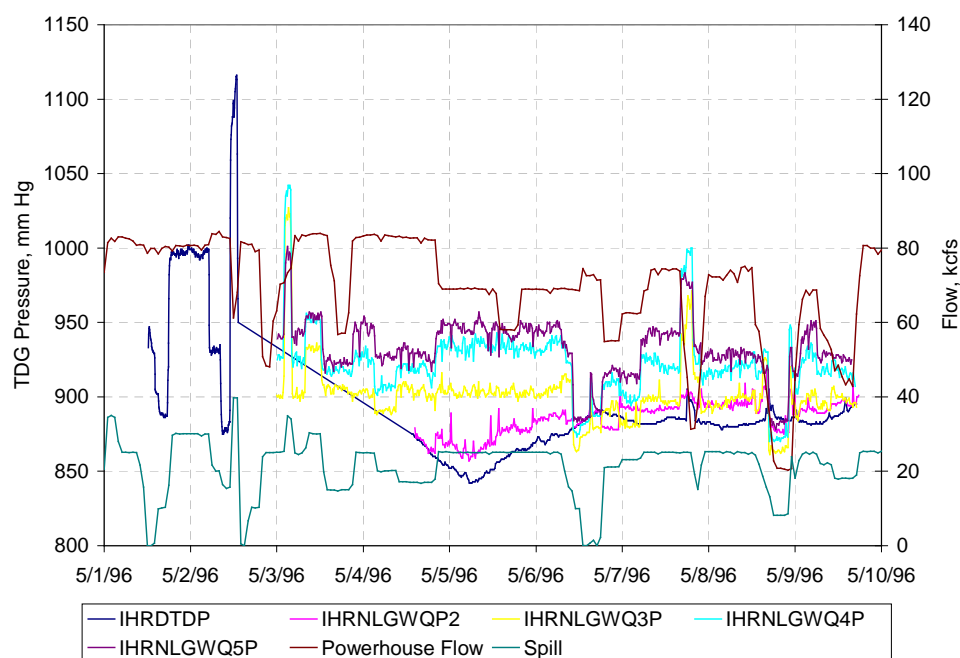
**Figure 192. TDG pressure measured by the fixed monitor at Ice Harbor dam during the Spring 1996 study period.**



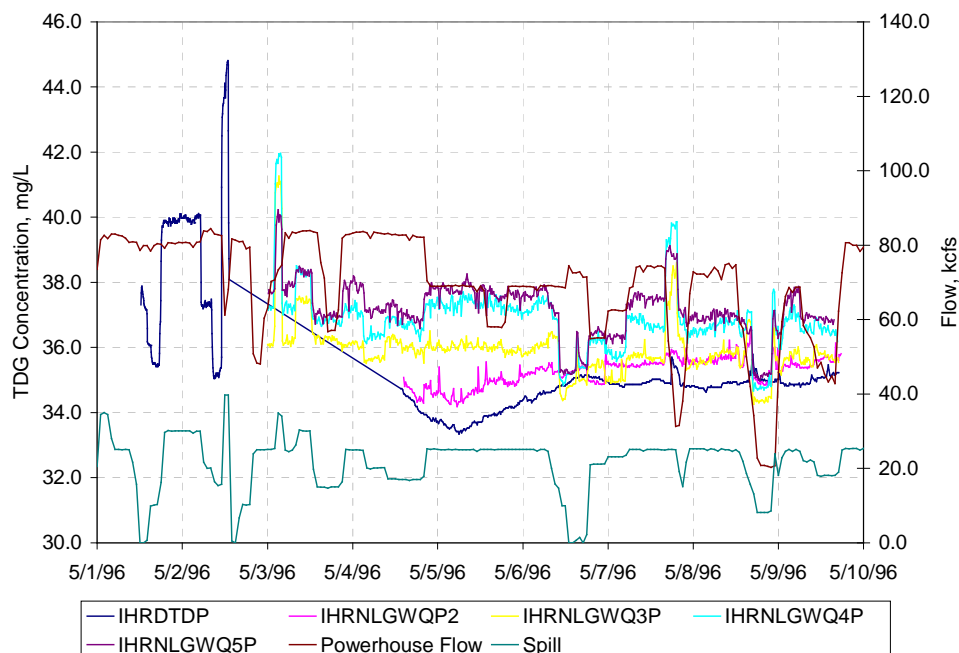
**Figure 193. Computed TDG concentration from fixed monitor measurements at Ice Harbor during the Spring 1996 study.**



**Figure 194. Water temperature measured by temporary monitors at Ice Harbor dam during the Spring 1996 study.**



**Figure 195. TDG pressure measured by temporary monitors at Ice Harbor dam during the Spring 1996 study period.**

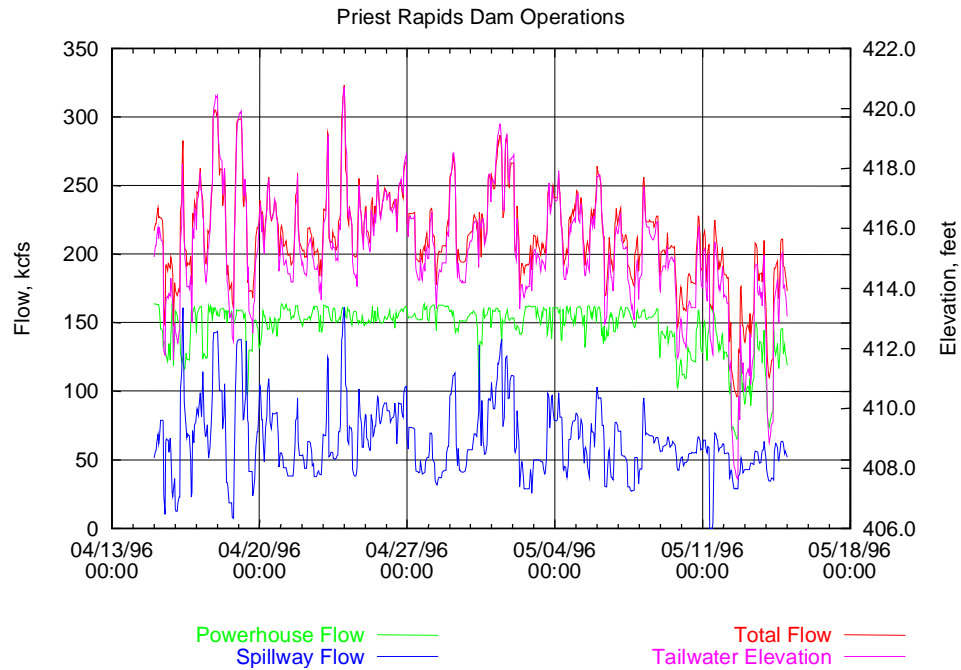


**Figure 196. Computed TDG concentration from temporary monitor measurements at Ice Harbor during the Spring 1996 study.**

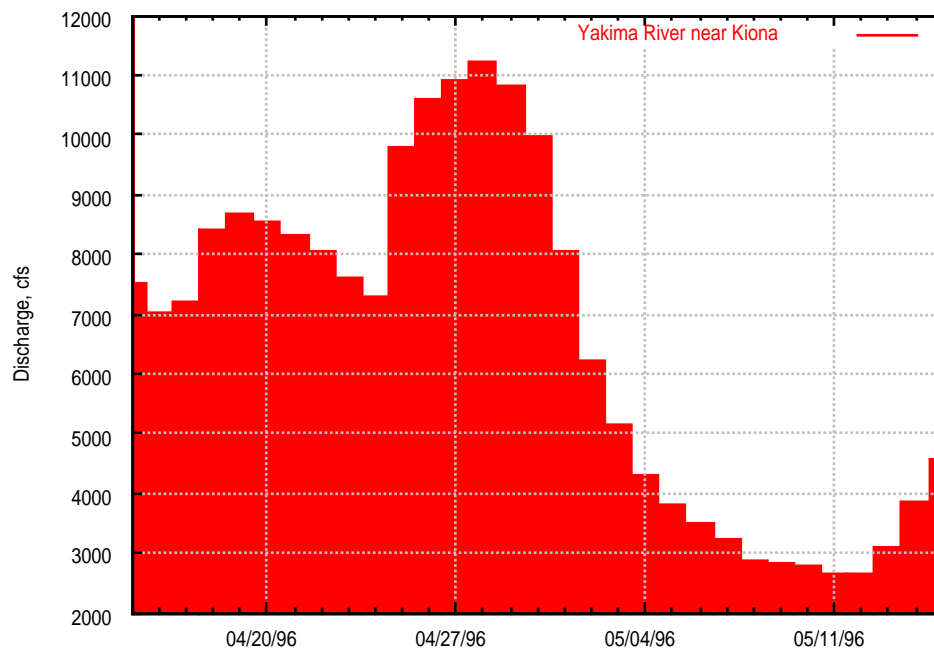
#### ***B.4 Clover Island Boundary***

##### ***B.4.1 Discharge***

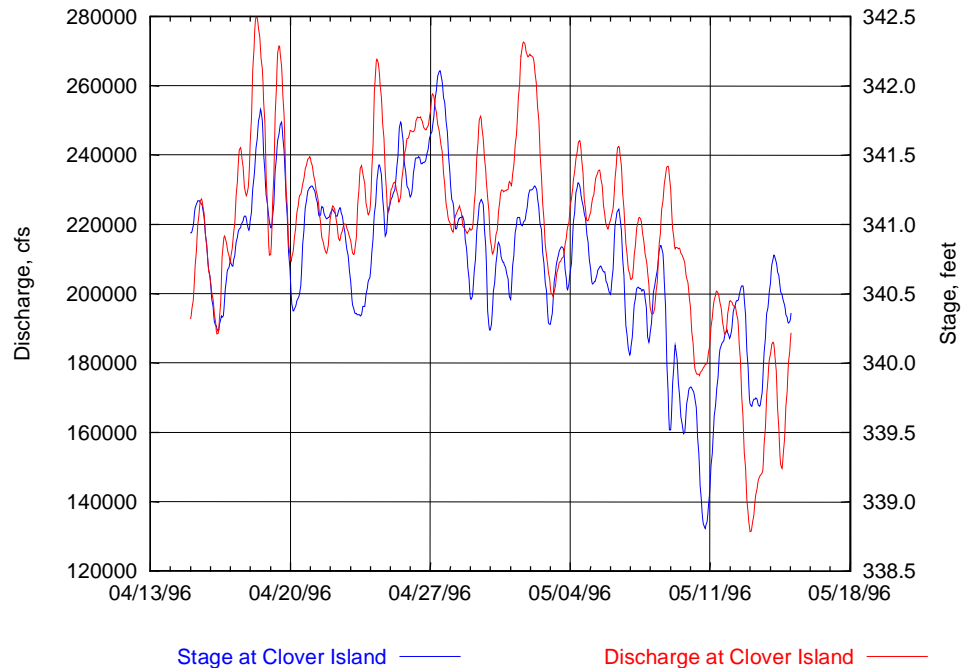
Discharge at Clover Island was estimated using a one-dimensional hydrodynamic model. The model used hourly dam operation data at Priest Rapids dam (Figure 197) and Ice Harbor dam (Figure 190), tributary inflow from the Yakima (Figure 198) and Walla Walla (Figure 204) Rivers, and forebay stages at McNary dam (Figure 203) to predict stage and discharge at Clover Island. Discharge and stage were predicted by the one-dimensional model are shown in Figure 199.



**Figure 197. Priest Rapids dam operations during the Spring 1996 study.**



**Figure 198. Yakima River flows during the Spring 1996 study.**

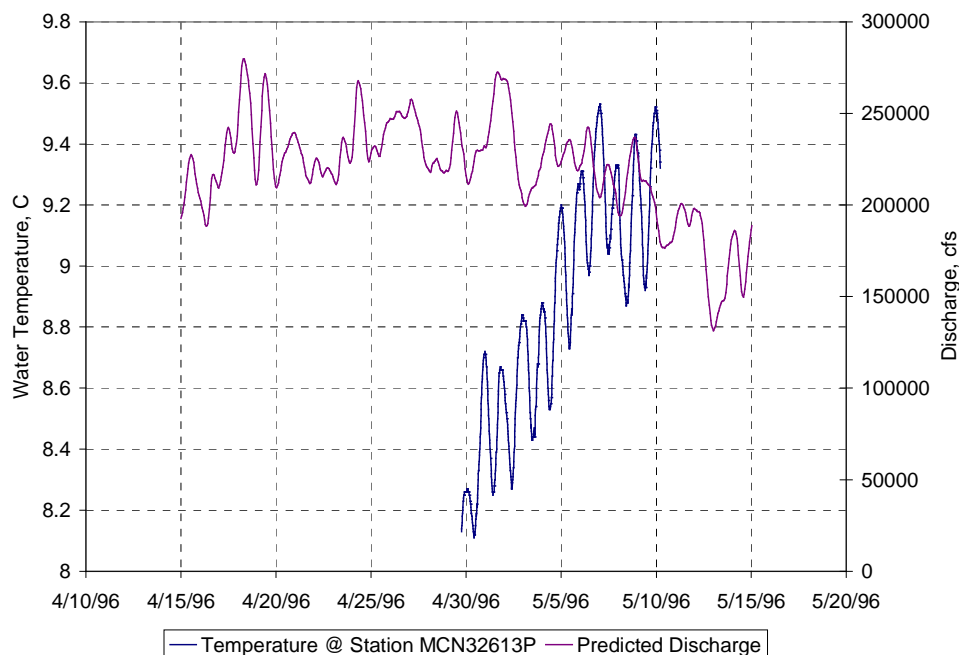


**Figure 199. Predicted discharge at Clover Island during Spring 1996 study.**

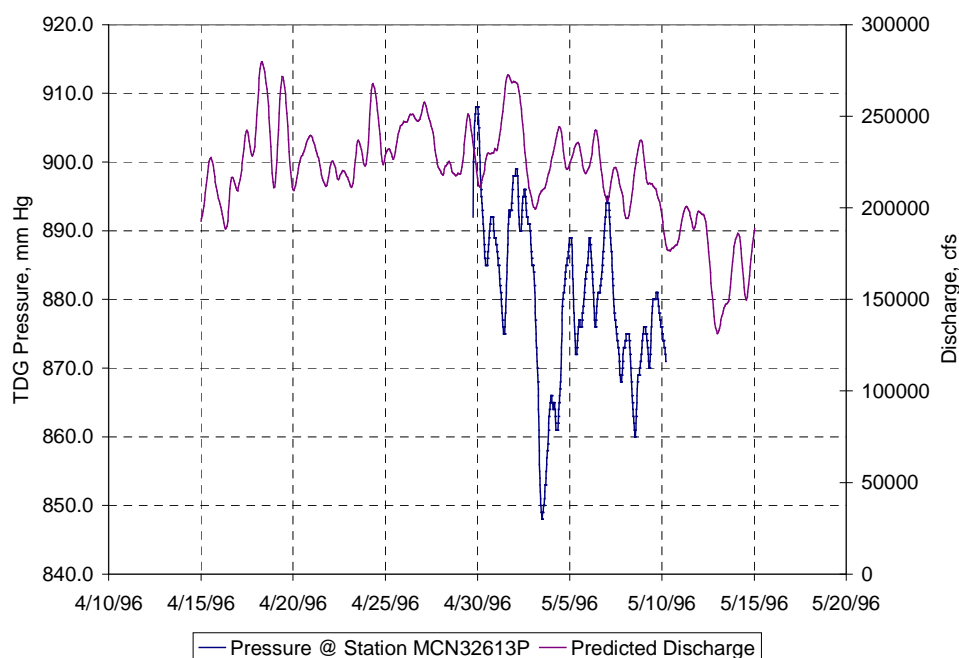
#### *B.4.2 Water Quality*

Water quality data was not directly available at Clover Island. The nearest downstream water quality monitor (station name "MCN32613P") was located approximately 2.5 miles downstream of the model boundary. Temperature (Figure 200) and TDG pressure (Figure 201) measured by the monitor, but delayed by one hour, were used for water quality at the Clover Island model boundary. Computed TDG concentrations are shown in Figure 202.

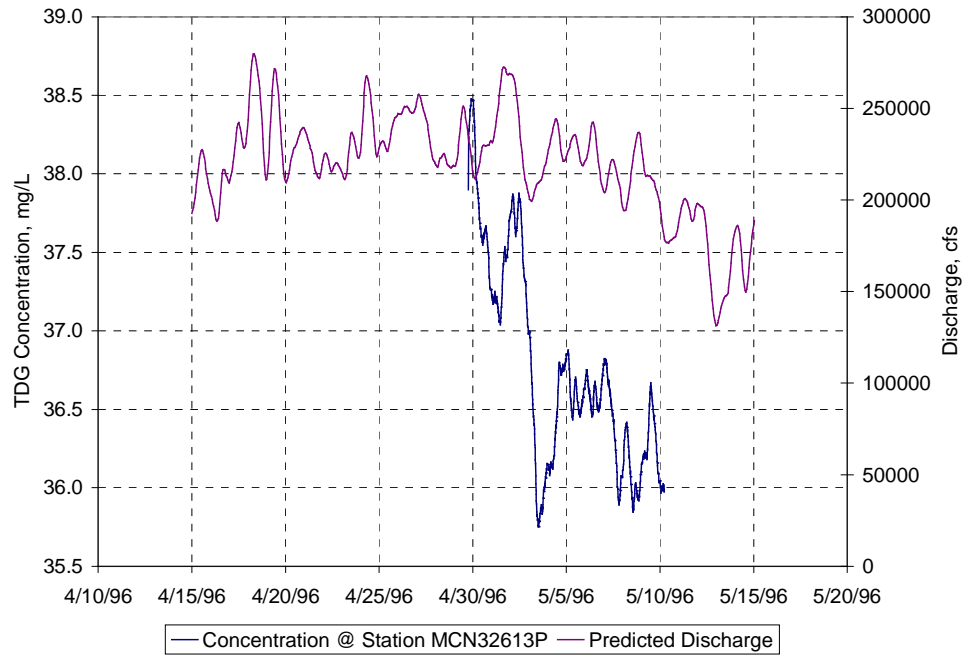




**Figure 200. Assumed water temperature for the Clover Island boundary during the Spring 1996 study.**



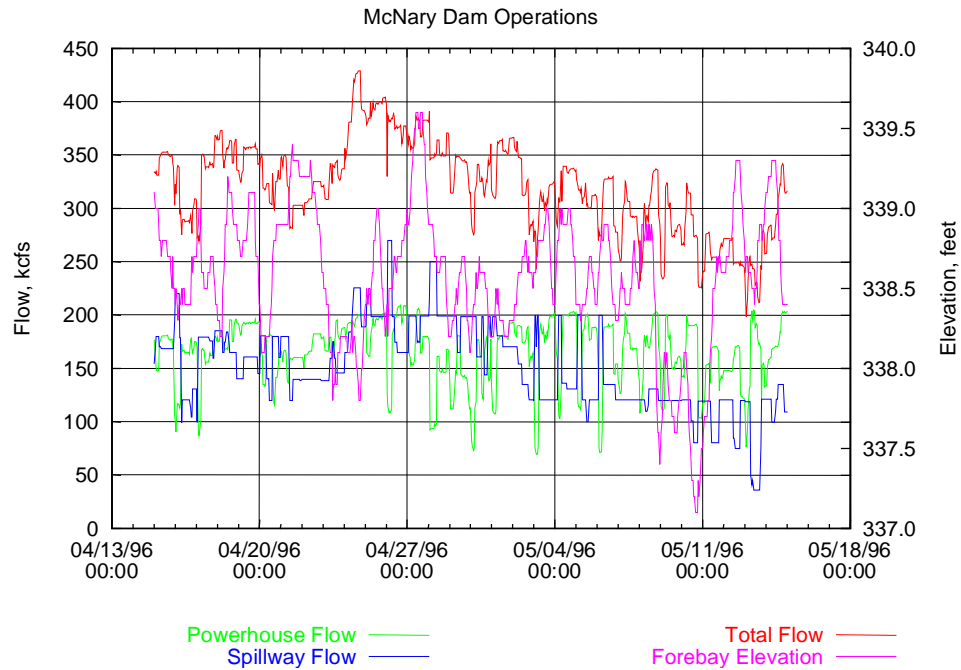
**Figure 201. Assumed TDG pressure for the Clover Island boundary during the Spring 1996 study.**



**Figure 202. Computed TDG concentration for the Clover Island boundary during the Spring 1996 study.**

### ***B.5 McNary Dam Boundary Operations***

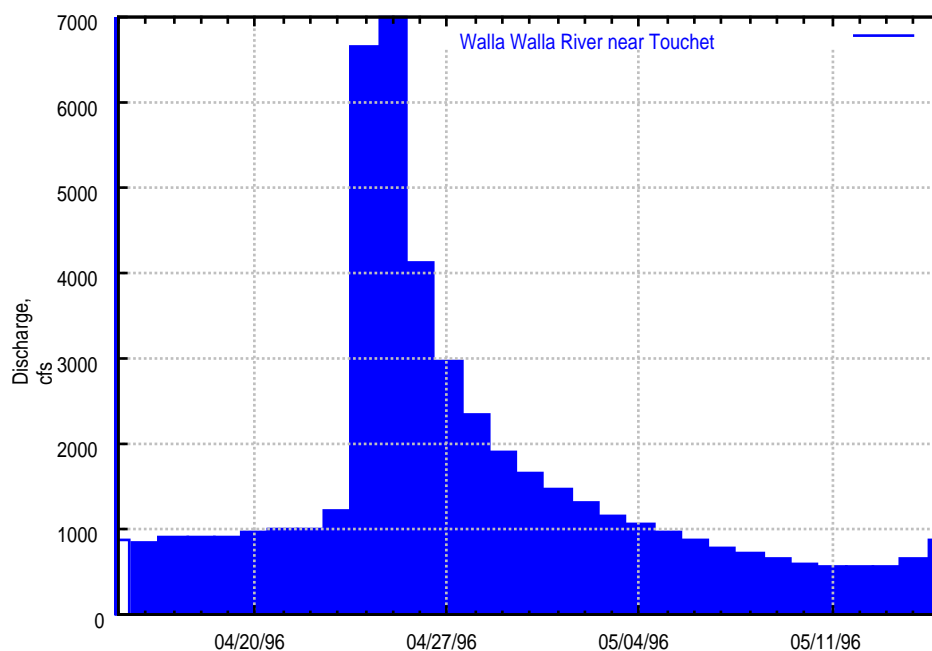
Forebay stage for McNary dam was obtained from hourly CHROMS operations data and is shown in Figure 203.



**Figure 203. McNary Dam operations during the spring 1996 study period.**

#### ***B.6 Walla Walla River Flows***

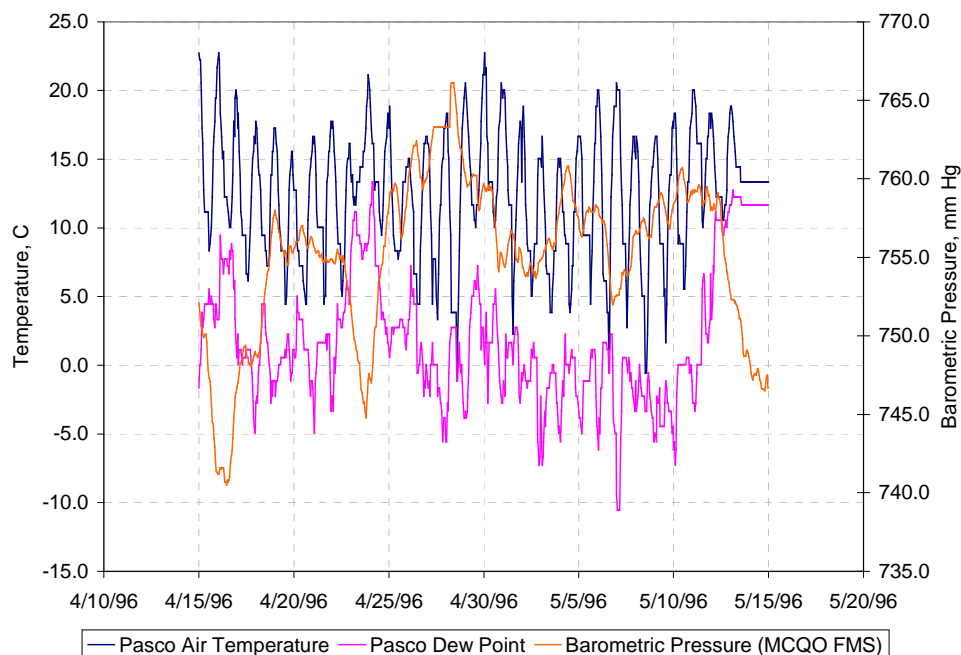
Flows from the Walla Walla River during the Spring 1996 study period are shown in Figure 204. They were very low, relative to Columbia River flows, and consequently, they were ignored.



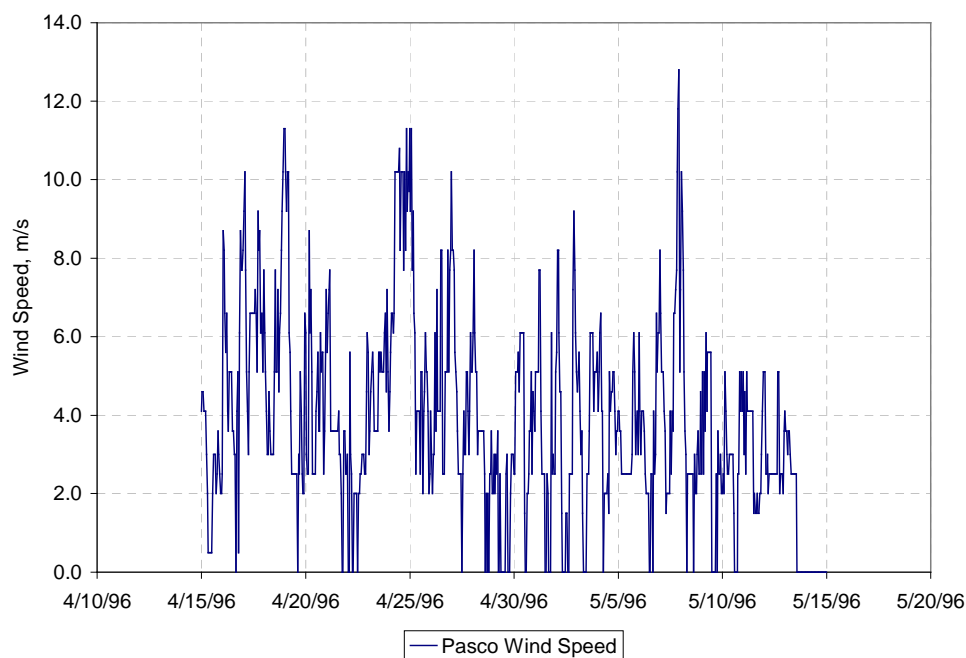
**Figure 204. Walla Walla River flows during the Spring 1996 study period.**

### ***B.7 Weather***

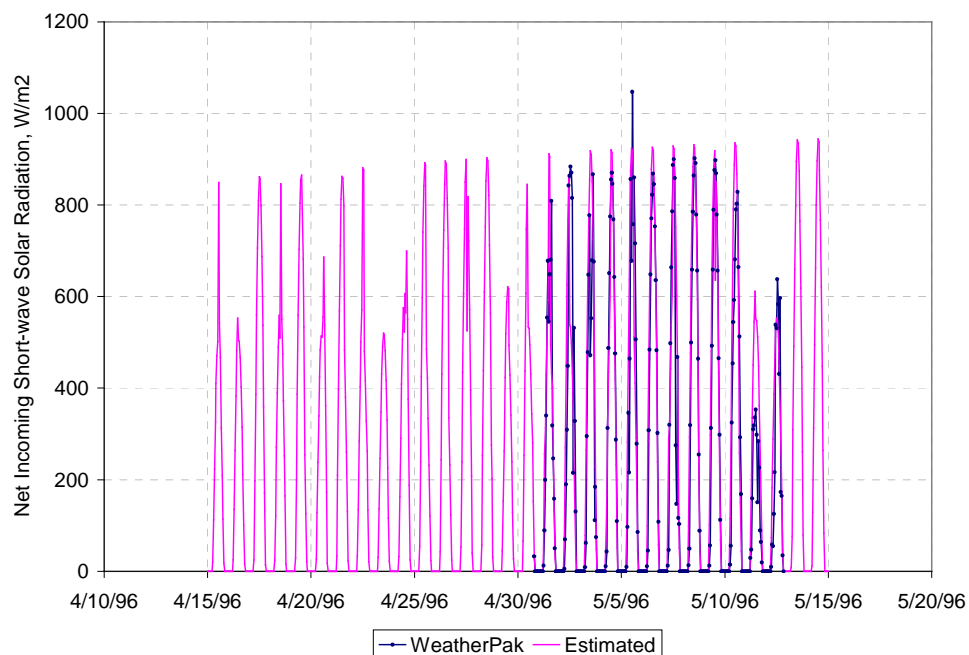
Atmospheric conditions were considered constant over the entire pool. Pasco, Washington, air and dew point temperature (Figure 205) and wind speed (Figure 206) were used from the NWS weather database. Barometric pressure measured by the MCQO FMS (also shown in Figure 205) was considered to apply over the entire modeled area. Short-wave radiation was available from the WeatherPak database for part the Spring 1996 study. The available radiation data was extended using NWS Pasco dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 207.



**Figure 205. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.**



**Figure 206. Wind speed used during the Spring 1996 study period.**



**Figure 207. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1996 study period.**

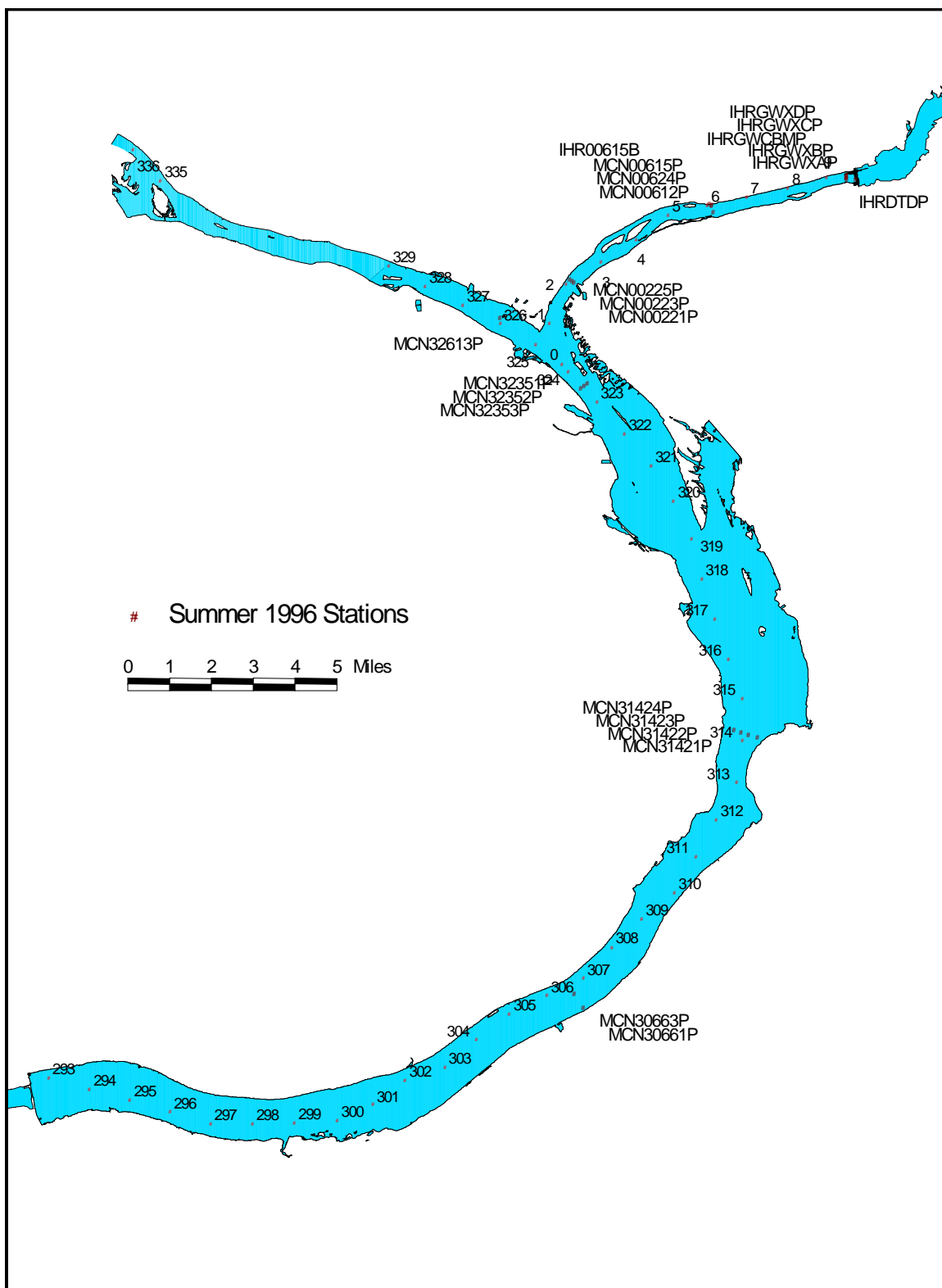
## Appendix C. Summer 1996 McNary Pool Study

### C.1 DGAS Data

The Summer 1996 McNary pool dissolved gas study started on July 1 and ended on July 12. A total of 23 water quality monitors were used. These stations, and their records, are listed in Table 83. Station locations are shown in Figure 208.

**Table 83. Dissolved gas monitor stations, and their records, used during the Summer 1996 McNary pool study.**

STATION	Start	End	Records
IHRGWXDP	7/1/96 10:00:00 AM	7/12/96 8:45:00 AM	1051
IHRGWXCP	7/1/96 10:15:00 AM	7/12/96 9:00:00 AM	1051
IHRGWCBMP	7/1/96 10:30:00 AM	7/11/96 4:50:00 AM	927
IHRDTDP	7/1/96 11:00:00 AM	7/12/96 11:42:00 AM	1047
IHRGWXBP	7/1/96 11:00:00 AM	7/12/96 8:45:00 AM	1047
IHRGWXAP	7/1/96 12:00:00 PM	7/2/96 6:30:00 PM	123
MCN00221P	7/1/96 1:00:00 PM	7/12/96 4:15:00 PM	1070
MCN00612P	7/1/96 1:13:00 PM	7/12/96 9:51:00 AM	1031
MCN00223P	7/1/96 1:15:00 PM	7/12/96 10:45:00 AM	1047
MCN00225P	7/1/96 1:30:00 PM	7/12/96 4:00:00 PM	1067
MCN00615P	7/1/96 1:30:00 PM	7/9/96 7:23:00 PM	783
MCN00624P	7/1/96 1:37:00 PM	7/12/96 9:45:00 AM	1029
MCN32613P	7/1/96 1:45:00 PM	7/12/96 11:30:00 AM	1048
IHR00615B	7/1/96 2:02:00 PM	7/12/96 9:55:00 AM	1028
MCN32351P	7/1/96 3:00:00 PM	7/12/96 11:45:00 AM	1044
MCN32352P	7/1/96 3:15:00 PM	7/12/96 11:45:00 AM	1043
MCN32353P	7/1/96 3:15:00 PM	7/12/96 11:45:00 AM	1043
MCN30663P	7/3/96 11:45:00 AM	7/12/96 11:00:00 AM	862
MCN30661P	7/3/96 12:15:00 PM	7/12/96 11:00:00 AM	860
MCN31422P	7/3/96 12:45:00 PM	7/12/96 10:45:00 AM	857
MCN31421P	7/3/96 1:00:00 PM	7/12/96 10:45:00 AM	856
MCN31423P	7/3/96 1:15:00 PM	7/12/96 3:30:00 PM	874
MCN31424P	7/3/96 1:30:00 PM	7/10/96 2:45:00 PM	677



**Figure 208. Dissolved gas monitor locations during the Summer 1996 study.**



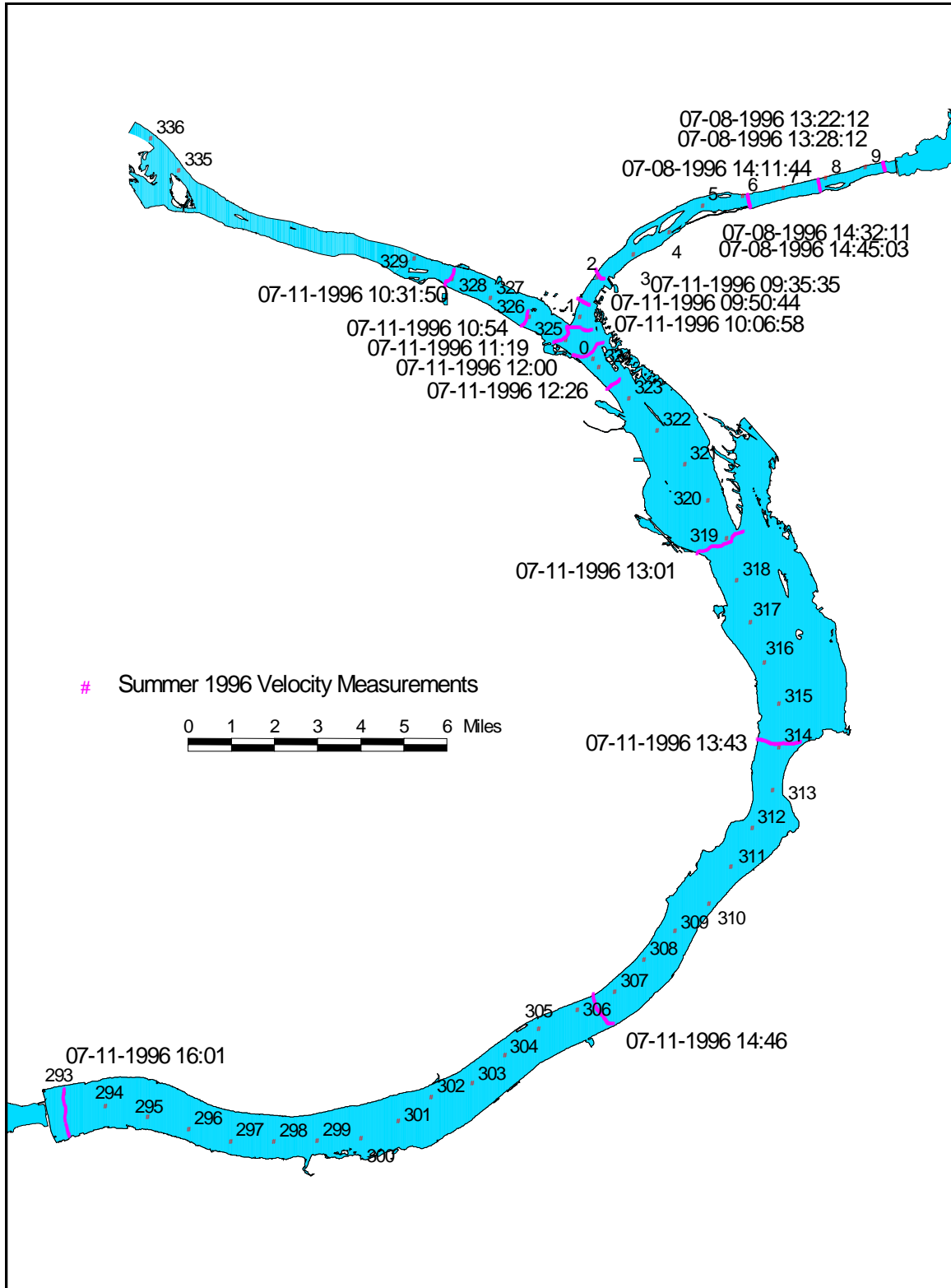
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***C.2 Velocity Data***

Velocity measurements were made along a total of 17 transects during the Summer 1996 study period. The transects are summarized in Table 84. Supplied measurement locations are shown in Figure 209.

**Table 84. Summary of ADCP transects made during the Summer 1996 study period.**

Date	Average		Number of
	Velocity	Depth	
07-08-1996 13:22	3.4	22.1	32
07-08-1996 13:28	2.8	24.2	24
07-08-1996 14:11	3.2	13.2	35
07-08-1996 14:32	2.9	14.0	40
07-08-1996 14:45	3.3	15.0	42
07-11-1996 09:35	1.2	22.6	46
07-11-1996 09:50	1.0	23.5	34
07-11-1996 10:06	1.0	19.7	53
07-11-1996 10:31	2.6	26.5	69
07-11-1996 10:54	2.6	32.3	56
07-11-1996 11:19	2.5	27.6	64
07-11-1996 12:00	2.3	26.2	66
07-11-1996 12:26	2.8	40.7	62
07-11-1996 13:01	1.4	27.7	125
07-11-1996 13:43	1.1	37.6	101
07-11-1996 14:46	1.0	49.5	96
07-11-1996 16:01	0.6	61.7	97

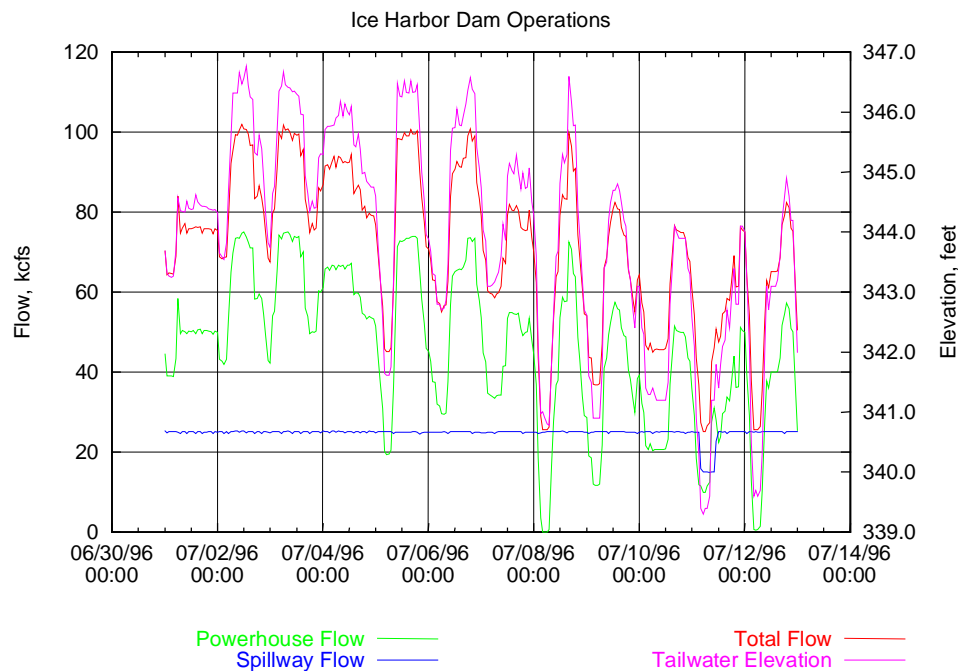


**Figure 209. Locations of ADCP velocity measurements during the Summer 1996 study period.**

### C.3 Ice Harbor Dam Boundary

#### C.3.1 Discharge

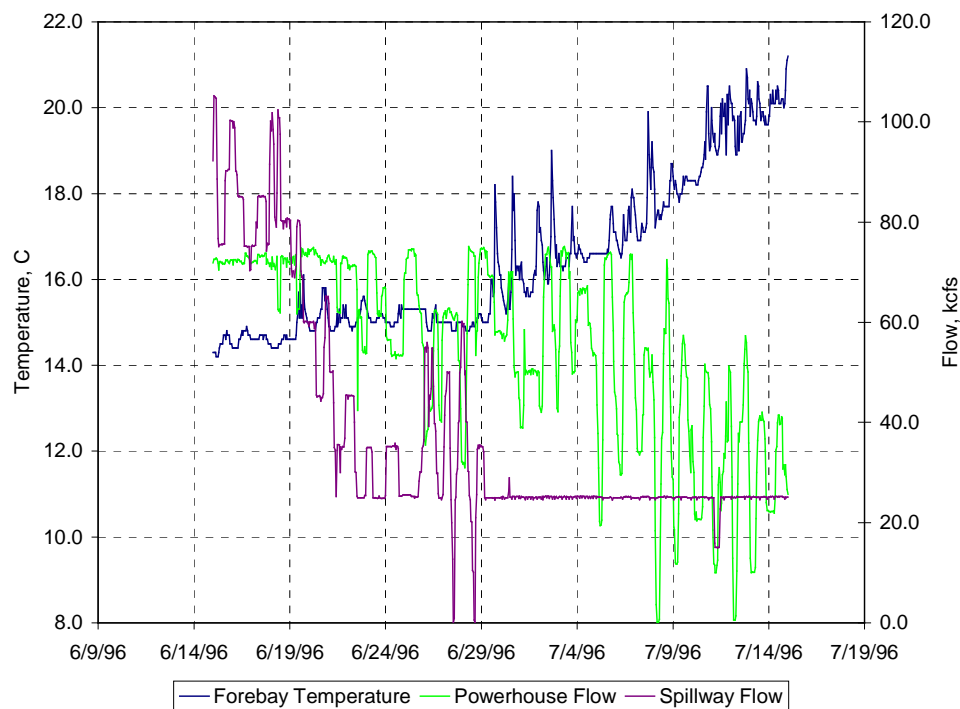
CHROMS operations data was used to establish the flow at the Ice Harbor dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Summer 1996 study period are shown in Figure 210. Ice Harbor Dam operations during the Summer 1996 study. These flows were uniformly distributed across the corresponding part of the model grid.



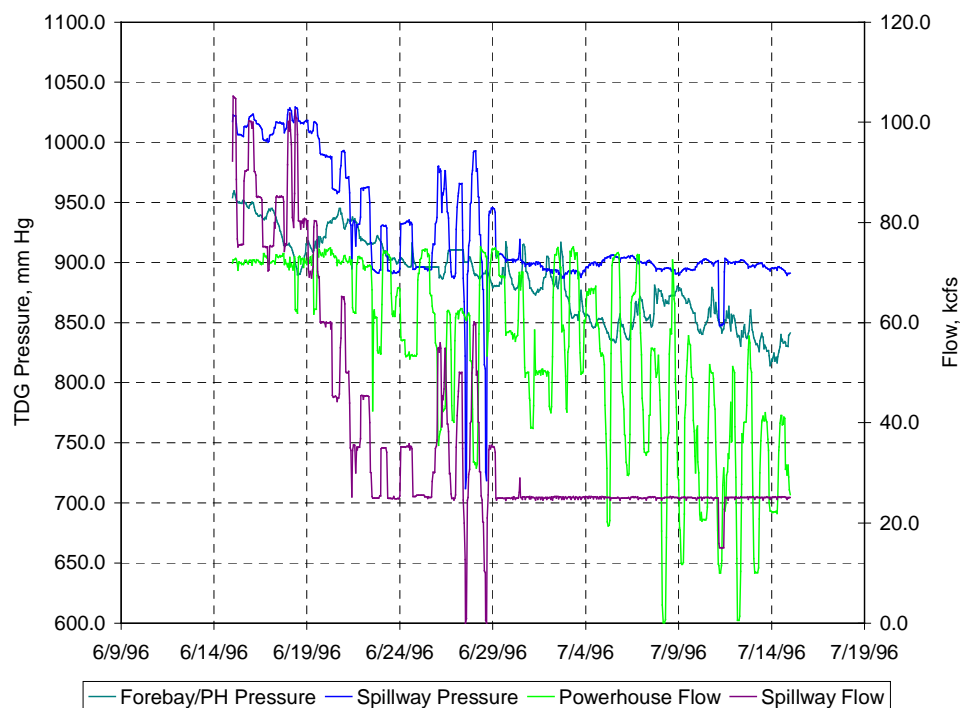
**Figure 210. Ice Harbor Dam operations during the Summer 1996 study.**

#### C.3.2 Water Quality

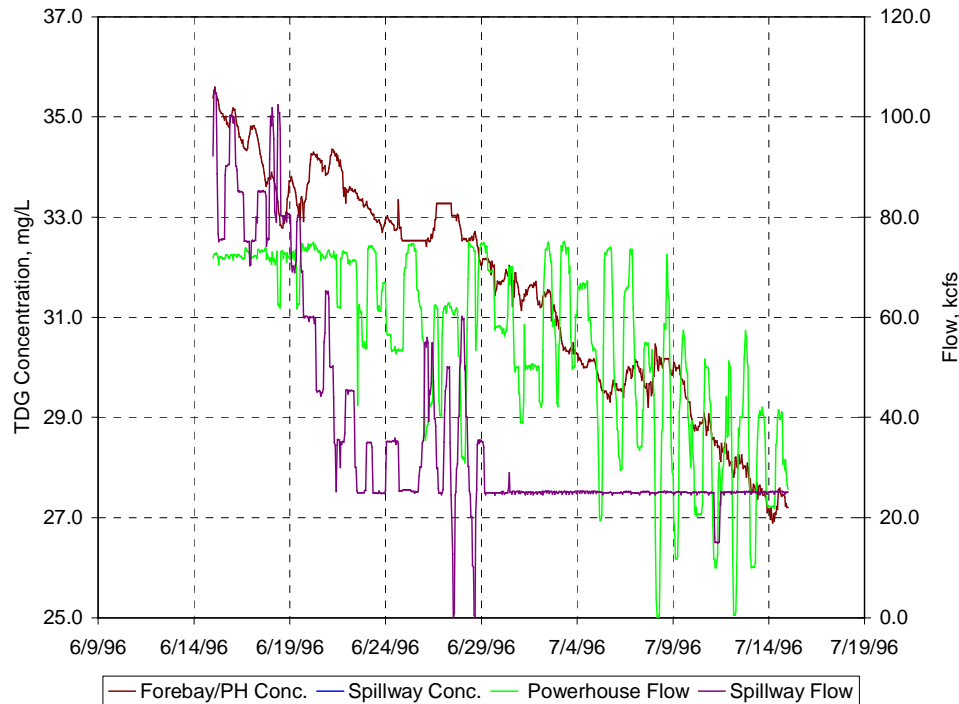
Initially, data from the fixed monitor located in the Ice Harbor forebay (station name "IHR") was used to establish water quality at the Ice Harbor boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 211) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 212) were used to compute TDG concentrations (Figure 213) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 212 and Figure 213, respectively) were estimated using the TDG sourcing function for Ice Harbor.



**Figure 211. Water temperature measured by the fixed monitor at Ice Harbor dam during the Summer 1996 study.**

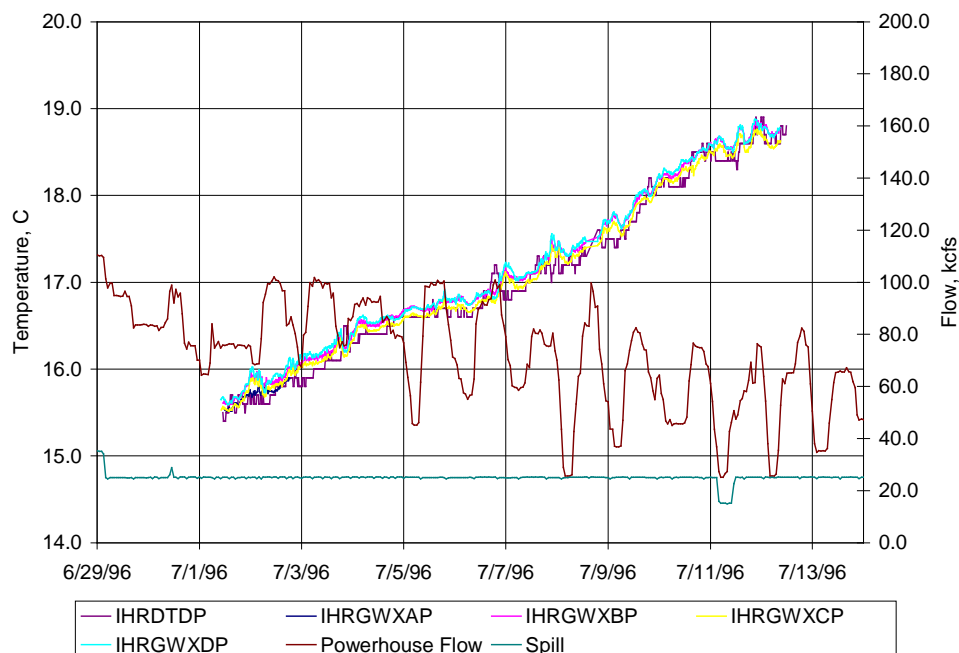


**Figure 212. TDG pressure measured by the fixed monitor at Ice Harbor dam during the Summer 1996 study period.**

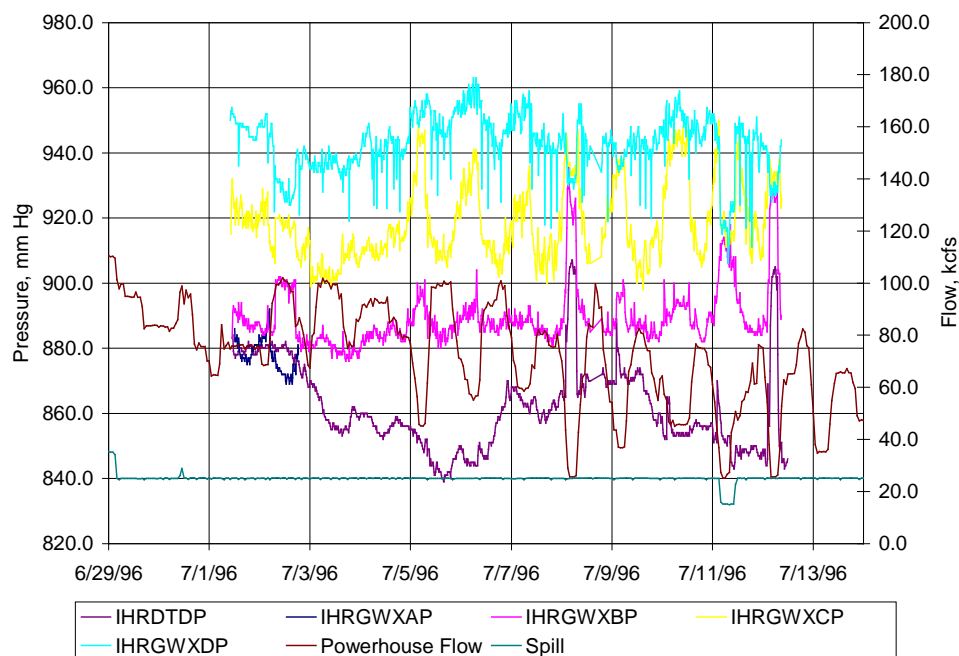


**Figure 213. TDG concentration computed from fixed monitor measurements at Ice Harbor during the Summer 1996 study.**

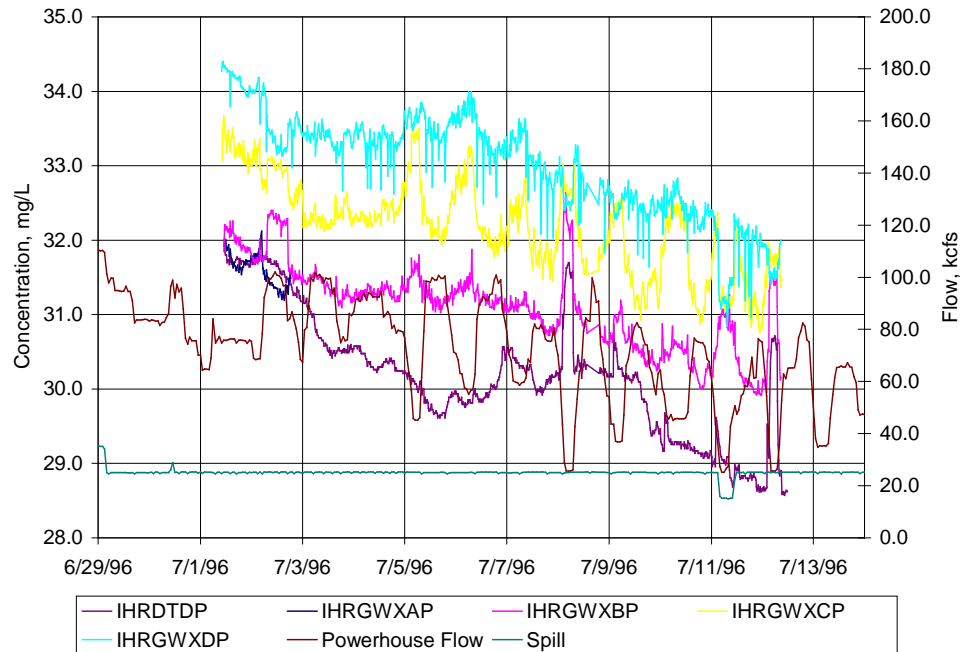
Ice Harbor dam model boundary temperature and dissolved gas concentrations were also established using the temporary pool study monitors. Five temporary monitors were located in the Ice Harbor tailrace during Summer 1996 study period. Measured temperatures, measured TDG pressures and computed TDG concentrations from these stations are shown in Figure 214, Figure 216, and Figure 216, respectively. Water temperature measured at the draft tube monitor, station IHRDTDP was used for both spillway and power house flows. TDG pressures and temperatures measured at the IHRDTDP station were used to compute TDG concentrations for powerhouse flows. TDG pressures and temperatures measured at the IHRWXDP station were used to compute TDG concentrations used for flows in the north half of the spillway; the IHRWXCP station was used for south half of the spillway.



**Figure 214. Water temperature measured by temporary monitors at Ice Harbor dam during the Summer 1996 study.**



**Figure 215. TDG pressure measured by temporary monitors at Ice Harbor dam during the Summer 1996 study period.**



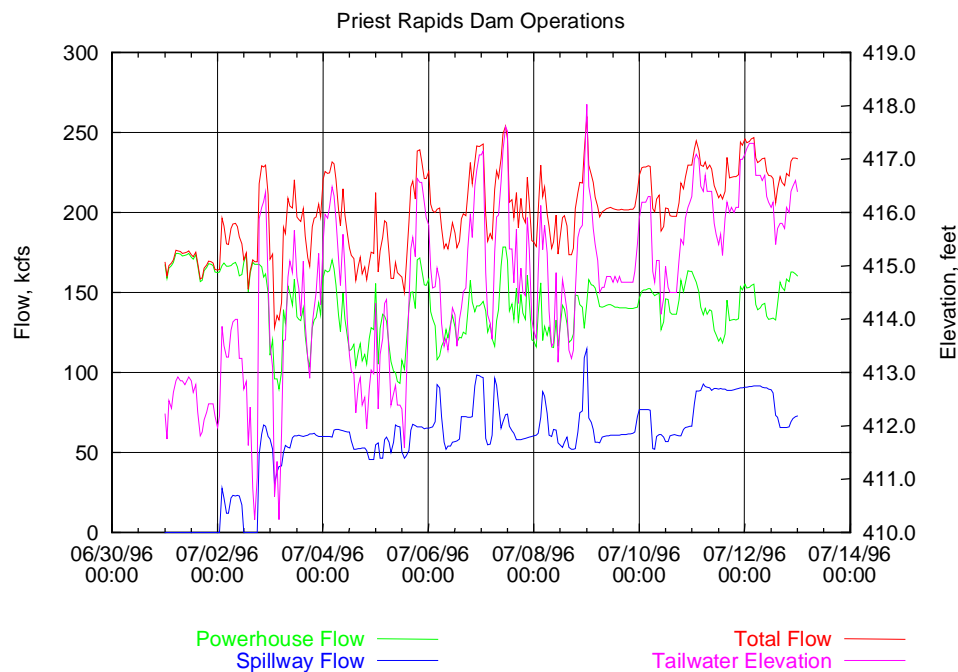
**Figure 216. Computed TDG concentration from temporary monitor measurements at Ice Harbor during the Summer 1996 study.**

#### ***C.4 Clover Island Boundary***

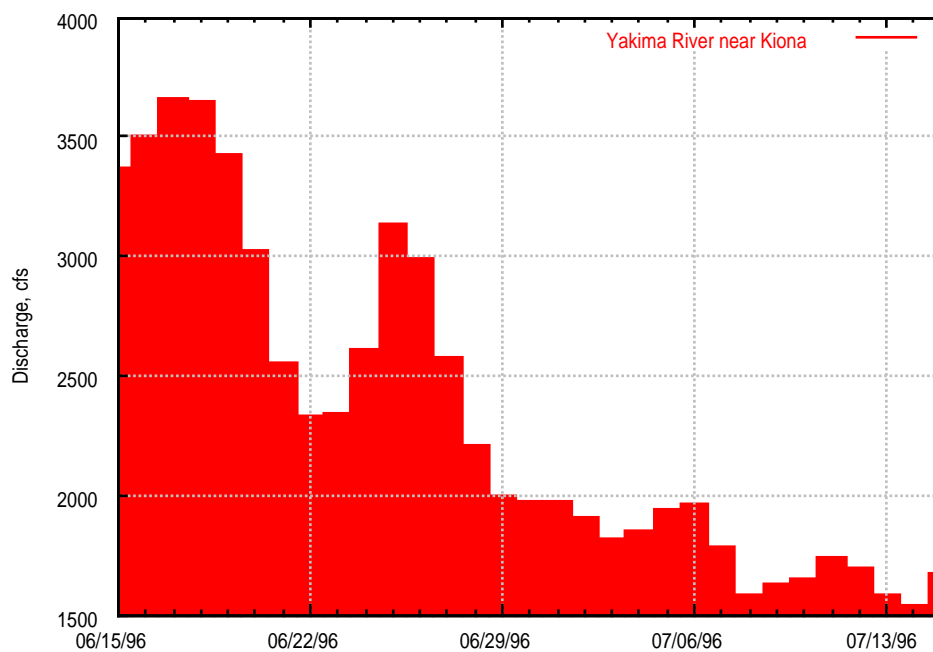
##### ***C.4.1 Discharge***

Discharge at Clover Island was estimated using a one-dimensional hydrodynamic model. The model used hourly dam operation data at Priest Rapids dam (Figure 217) and Ice Harbor dam (Figure 210), tributary inflow from the Yakima (Figure 218) and Walla Walla (Figure 224) Rivers, and forebay stages at McNary dam (Figure 223) to predict stage and discharge at Clover Island. Discharge and stage were predicted by the one-dimensional model are shown in.





**Figure 217. Priest Rapids dam operations during the Summer 1996 study.**

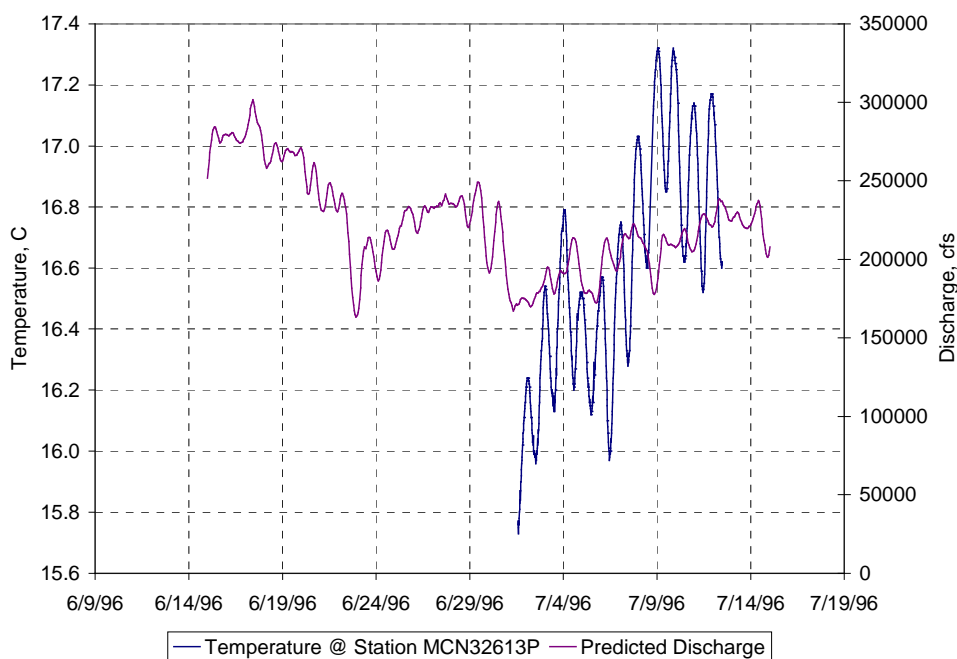


**Figure 218. Yakima River flows during the Summer 1996 study.**

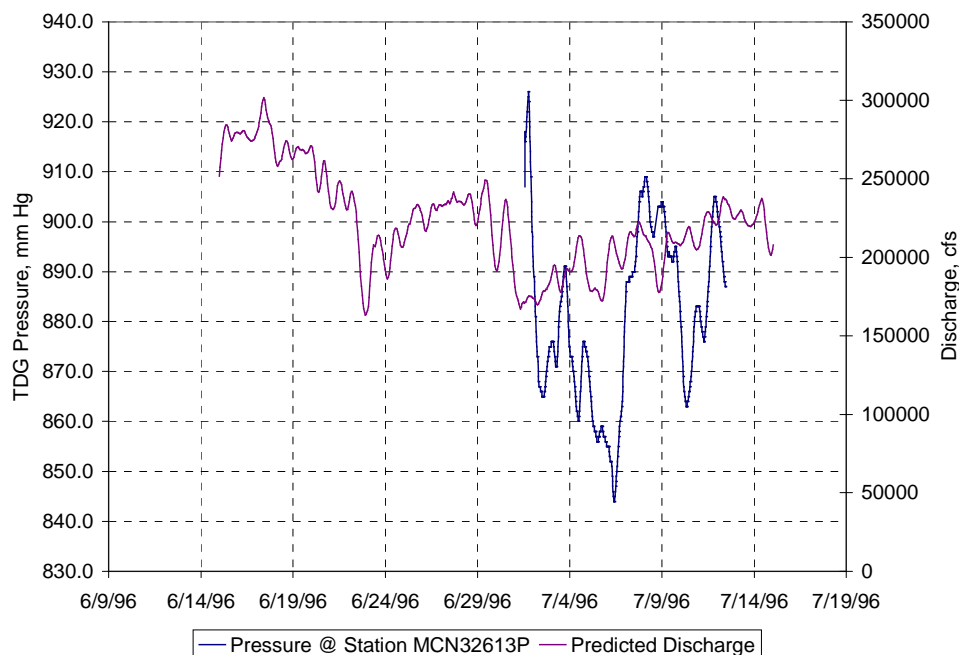
**Figure 219. Predicted discharge at Clover Island during the Summer 1996 study period.**

#### *C.4.2 Water Quality*

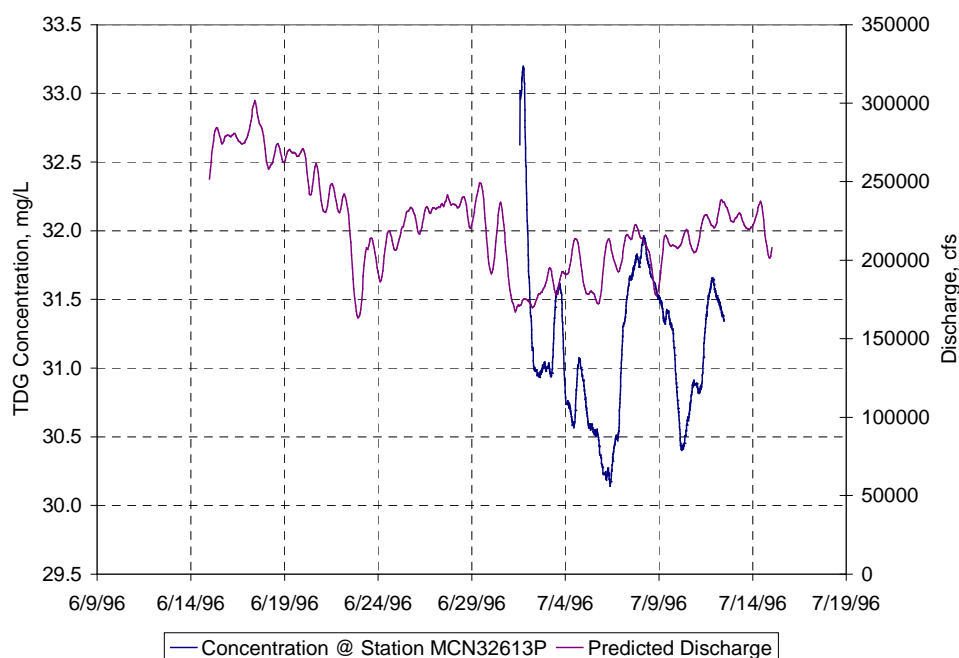
Water quality data was not directly available at Clover Island. The nearest downstream water quality monitor (station name "MCN32613P") was located approximately 2.5 miles downstream of the model boundary. Temperature (Figure 220) and TDG pressure (Figure 221) measured by the monitor, but delayed by one hour, were used for water quality at the Clover Island model boundary. Computed TDG concentrations are shown in Figure 222.



**Figure 220. Assumed water temperature for the Clover Island boundary during the Summer 1996 study.**



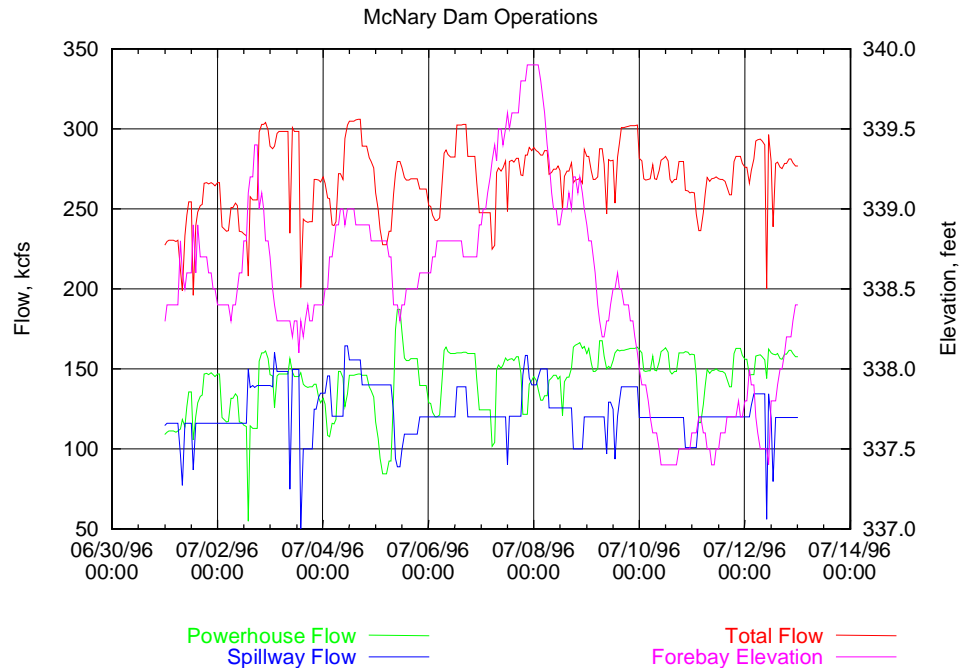
**Figure 221. Assumed TDG pressure for the Clover Island boundary during the Summer 1996 study.**



**Figure 222. Computed TDG concentration for the Clover Island boundary during the Summer 1996 study period.**

### C.5 McNary Dam Boundary Operations

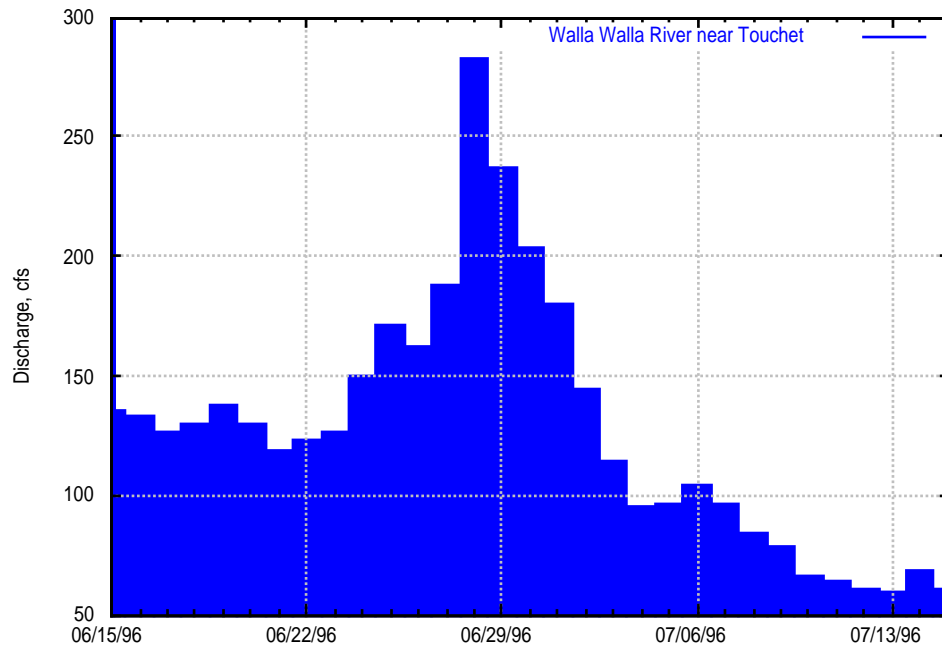
Forebay stage for McNary dam was obtained from hourly CHROMS operations data and is shown in Figure 223.



**Figure 223. McNary Dam operations during the Summer 1996 study period.**

### C.6 Walla Walla River Flows

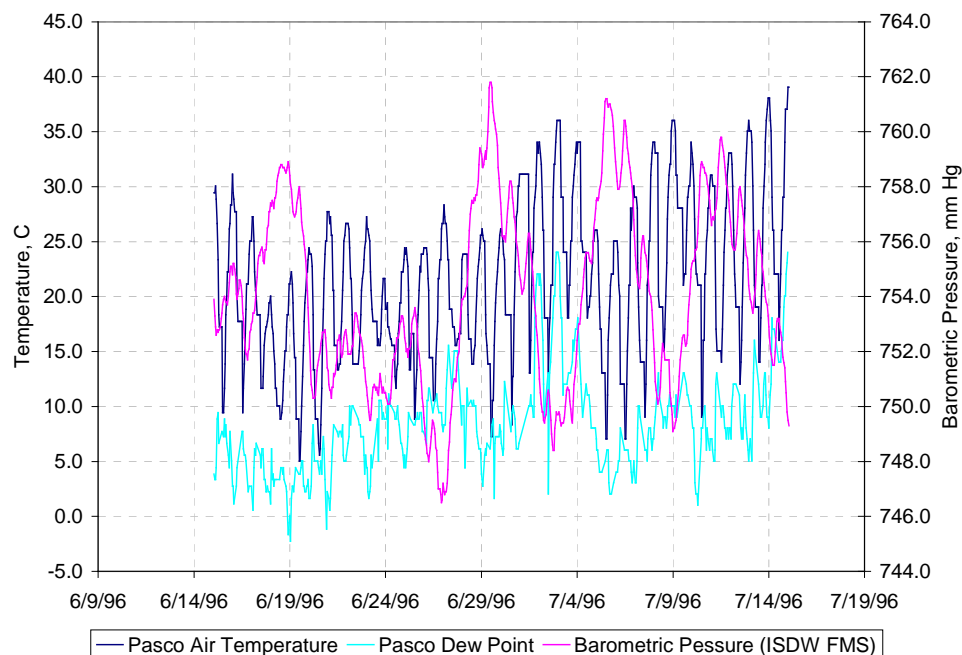
Flows from the Walla Walla River during the Summer 1996 study period were extremely low compared to Columbia River flows.



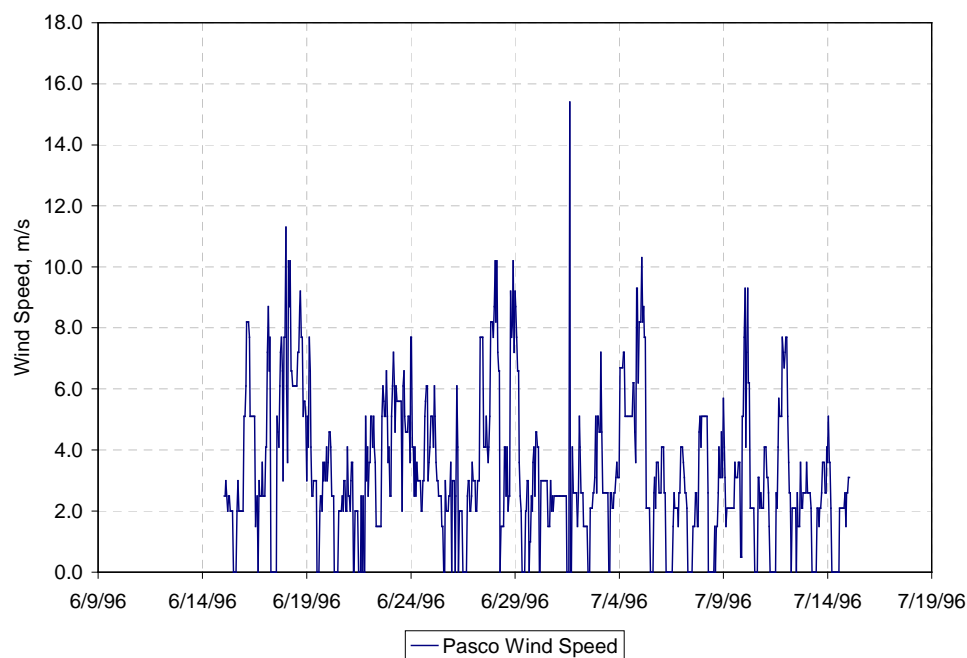
**Figure 224. Walla Walla River flows during the Summer 1996 study period.**

### ***C.7 Weather***

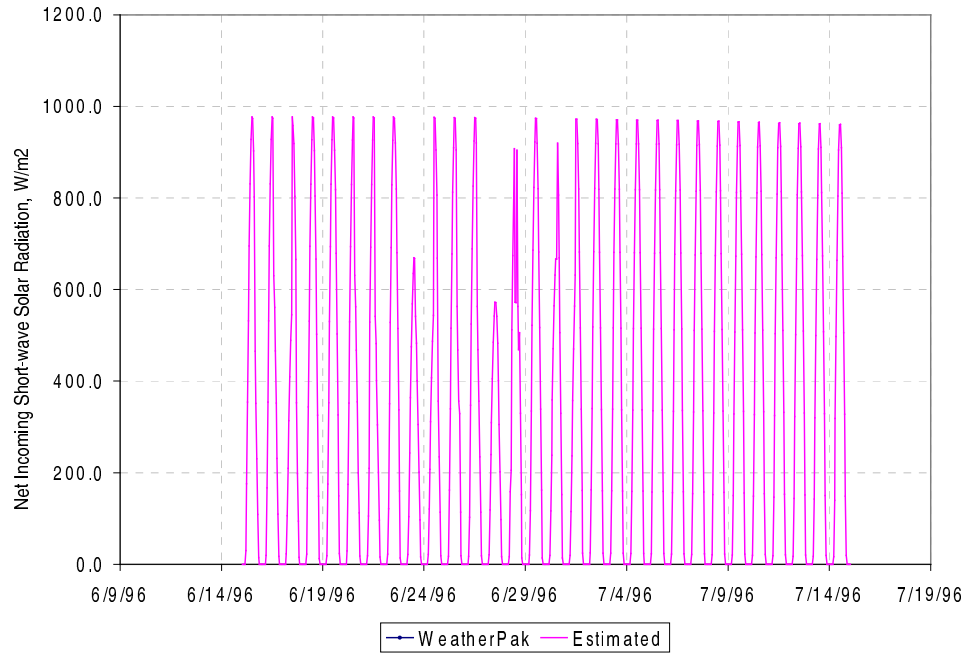
Atmospheric conditions were considered constant over the entire pool. Pasco, Washington, air and dew point temperature (Figure 225) and wind speed (Figure 226) were used from the NWS weather database. Barometric pressure measured by the IDSW FMS (also shown in Figure 225) was considered to apply over the entire modeled area. Short-wave radiation was not available from the WeatherPak database during the Summer 1996 study. Total incoming radiation data was estimated using NWS Pasco dew point and cloud cover data. Cloud cover was missing in the NWS database for Pasco after June 30. Cloud cover was assumed to be zero (clear skies) if cloud cover data was missing from the Pasco record. Net incoming solar radiation based both on the estimated total solar radiation is shown in Figure 227.



**Figure 225. Air temperature, dew point, and barometric pressure used during the Summer 1996 study period.**



**Figure 226. Wind speed used during the Summer 1996 study period.**



**Figure 227. Net incoming short-wave solar radiation based estimated total radiation used during the Summer 1996 study period**

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## **Appendix D. Spring 1997 McNary Pool Study**

### ***D.1 DGAS Data***

The Spring 1997 McNary pool dissolved gas study started on July 1 and ended on July 12. A total of 23 water quality monitors were used. These stations, and their records, are listed in Table 85. Station locations are shown in Figure 228.

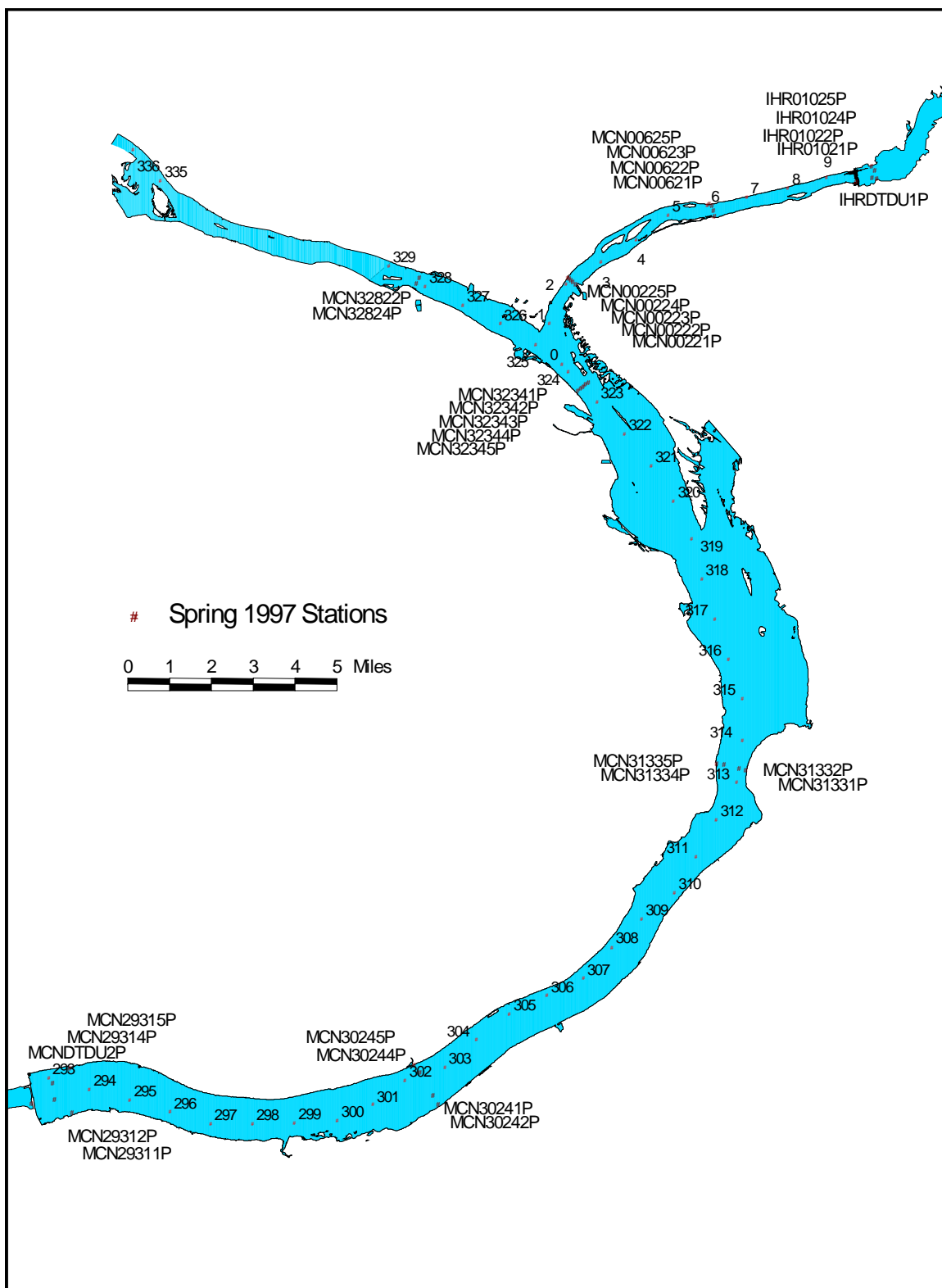
### ***D.2 Velocity Data***

Velocity measurements were made along a total of 47 transects during the Spring 1997 study period. The transects are summarized in Table 86. Supplied measurement locations are shown in Figure 229.



**Table 85. Dissolved gas monitor stations, and their records, used during the Spring 1997 McNary pool study.**

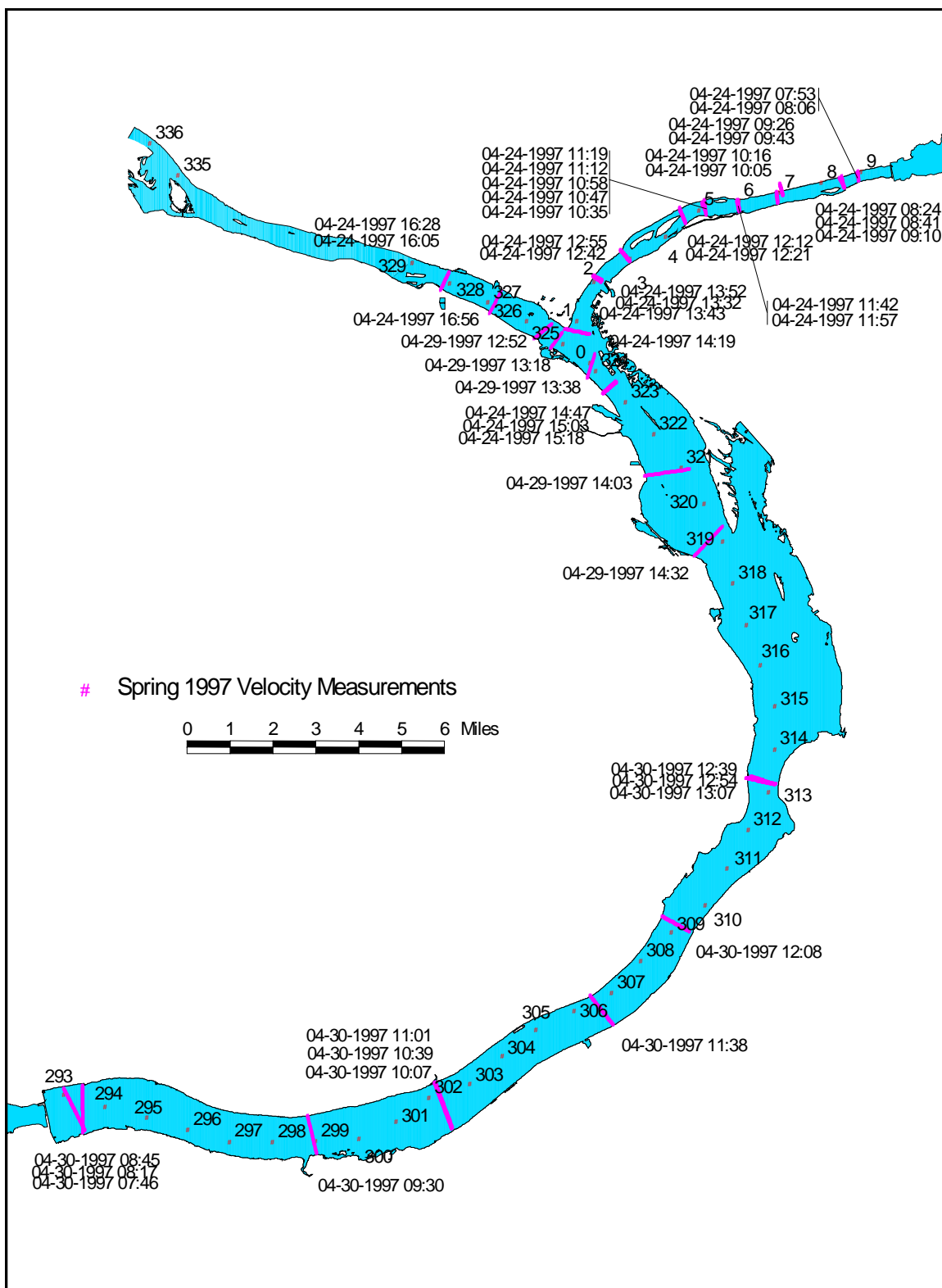
STATION	Start	End	Records
MCN30245P	4/22/97 12:20:00 PM	5/3/97 8:58:00 AM	1031
MCN00621P	4/23/97 11:00:00 AM	5/1/97 11:00:00 AM	769
MCN00623P	4/23/97 11:00:00 AM	5/1/97 11:30:00 AM	771
MCN00625P	4/23/97 11:00:00 AM	5/1/97 12:00:00 PM	773
MCN00622P	4/23/97 11:45:00 AM	5/1/97 11:15:00 AM	767
MCNDTUDU2P	4/23/97 8:00:00 PM	5/3/97 11:00:00 AM	232
IHRDTDU1P	4/23/97 8:00:00 PM	5/1/97 3:00:00 PM	188
IHR03002P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
MCN00225P	4/23/97 11:00:00 PM	5/1/97 7:45:00 AM	708
MCN00221P	4/23/97 11:00:00 PM	5/1/97 7:45:00 AM	708
IHR04075P	4/23/97 11:00:00 PM	5/2/97 9:00:00 AM	809
IHR04073P	4/23/97 11:00:00 PM	5/2/97 9:00:00 AM	809
IHR04071P	4/23/97 11:00:00 PM	5/2/97 9:00:00 AM	809
IHR03005P	4/23/97 11:00:00 PM	5/2/97 10:00:00 AM	813
MCN00223P	4/23/97 11:00:00 PM	4/26/97 4:45:00 AM	178
IHR03003P	4/23/97 11:00:00 PM	5/2/97 10:00:00 AM	813
MCN00224P	4/23/97 11:00:00 PM	5/1/97 7:30:00 AM	707
IHR03001P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
IHR02005P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
IHR02004P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
IHR02002P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
IHR02001P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817
IHR01025P	4/23/97 11:00:00 PM	5/1/97 2:00:00 PM	733
IHR01024P	4/23/97 11:00:00 PM	5/1/97 2:00:00 PM	733
IHR01022P	4/23/97 11:00:00 PM	5/1/97 2:00:00 PM	733
IHR03004P	4/23/97 11:00:00 PM	5/2/97 10:00:00 AM	813
MCN29315P	4/23/97 11:00:00 PM	5/3/97 9:00:00 AM	227
MCN32342P	4/23/97 11:00:00 PM	5/1/97 9:00:00 AM	713
MCN32341P	4/23/97 11:00:00 PM	5/1/97 9:00:00 AM	713
MCN31335P	4/23/97 11:00:00 PM	5/2/97 2:00:00 PM	829
MCN31332P	4/23/97 11:00:00 PM	5/2/97 1:45:00 PM	828
MCN31331P	4/23/97 11:00:00 PM	5/2/97 2:00:00 PM	829
MCN32344P	4/23/97 11:00:00 PM	5/1/97 8:15:00 AM	710
MCN30244P	4/23/97 11:00:00 PM	5/3/97 9:15:00 AM	906
MCN00222P	4/23/97 11:00:00 PM	5/1/97 7:45:00 AM	708
MCN30241P	4/23/97 11:00:00 PM	5/3/97 9:00:00 AM	905
MCN32343P	4/23/97 11:00:00 PM	5/1/97 9:45:00 AM	716
MCN29314P	4/23/97 11:00:00 PM	5/3/97 7:00:00 AM	225
MCN29312P	4/23/97 11:00:00 PM	5/3/97 8:00:00 AM	901
MCN29311P	4/23/97 11:00:00 PM	4/28/97 12:45:00 PM	440
MCN32345P	4/23/97 11:00:00 PM	5/1/97 9:00:00 AM	713
MCN32822P	4/23/97 11:00:00 PM	5/1/97 10:00:00 AM	180
MCN32824P	4/23/97 11:00:00 PM	5/1/97 9:00:00 AM	713
IHR01021P	4/23/97 11:00:00 PM	5/1/97 2:00:00 PM	733
MCN30242P	4/23/97 11:00:00 PM	5/3/97 9:00:00 AM	905
MCN31334P	4/23/97 11:15:00 PM	5/2/97 1:45:00 PM	827
LMNDTUDU2P	4/24/97 4:00:00 PM	5/2/97 12:00:00 PM	189
MCN31424P	7/3/96 1:30:00 PM	7/10/96 2:45:00 PM	677



**Figure 228. Dissolved gas monitor locations during the Spring 1997 study.**

**Table 86. Summary of ADCP transects made during the Spring 1997 study period.**

DateLabel	Average		Number of
	Velocity	Depth	
Measurements			
04-24-1997 07:53	6.7	22.2	34
04-24-1997 08:06	6.4	21.3	39
04-24-1997 08:24	7.0	20.0	44
04-24-1997 08:41	6.6	17.9	41
04-24-1997 09:10	6.6	19.3	46
04-24-1997 09:26	6.3	18.5	50
04-24-1997 09:43	6.0	18.4	52
04-24-1997 10:05	6.2	20.9	46
04-24-1997 10:16	6.4	21.1	47
04-24-1997 10:35	7.2	18.1	43
04-24-1997 10:47	6.9	18.4	43
04-24-1997 10:58	7.0	18.2	45
04-24-1997 11:12	6.8	18.7	42
04-24-1997 11:19	7.0	18.1	44
04-24-1997 11:42	5.6	19.3	52
04-24-1997 11:57	5.9	19.6	49
04-24-1997 12:12	5.6	19.3	55
04-24-1997 12:21	5.4	19.0	57
04-24-1997 12:42	4.3	20.2	64
04-24-1997 12:55	4.2	20.3	64
04-24-1997 13:32	5.2	25.5	46
04-24-1997 13:43	5.3	25.7	45
04-24-1997 13:52	5.3	25.7	46
04-24-1997 14:19	3.1	22.1	105
04-24-1997 14:47	4.4	43.2	70
04-24-1997 15:03	4.4	44.2	69
04-24-1997 15:18	4.6	43.7	71
04-24-1997 16:05	2.4	34.5	80
04-24-1997 16:28	2.5	34.8	80
04-24-1997 16:56	2.5	28.1	98
04-29-1997 12:52	2.6	33.1	99
04-29-1997 13:18	2.8	32.4	92
04-29-1997 13:38	4.8	32.8	112
04-29-1997 14:03	2.6	27.3	171
04-29-1997 14:32	2.5	34.7	158
04-30-1997 07:46	1.1	65.5	181
04-30-1997 08:17	1.1	64.7	184
04-30-1997 08:45	1.1	65.5	181
04-30-1997 09:30	1.5	59.4	149
04-30-1997 10:07	1.3	53.3	196
04-30-1997 10:39	1.3	52.0	186
04-30-1997 11:01	1.3	53.0	187
04-30-1997 11:38	1.7	54.2	138
04-30-1997 12:08	2.0	53.9	128
04-30-1997 12:39	2.2	51.3	118
04-30-1997 12:54	2.2	51.6	112
04-30-1997 13:07	2.2	50.7	115

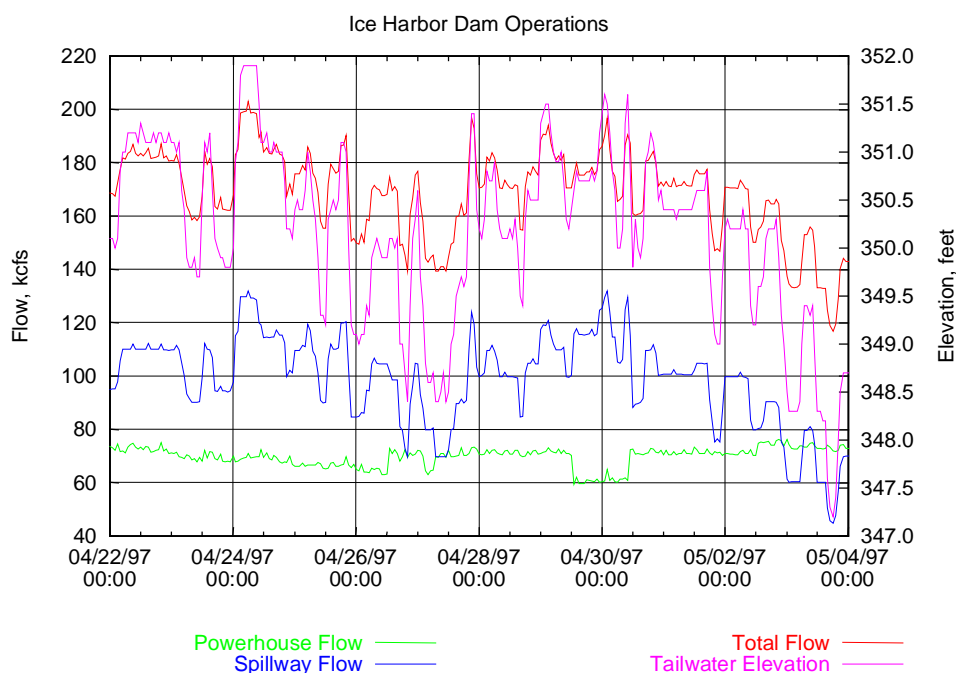


**Figure 229. Locations of ADCP velocity measurements during the Spring 1997 study period.**

### D.3 Ice Harbor Dam Boundary

#### D.3.1 Discharge

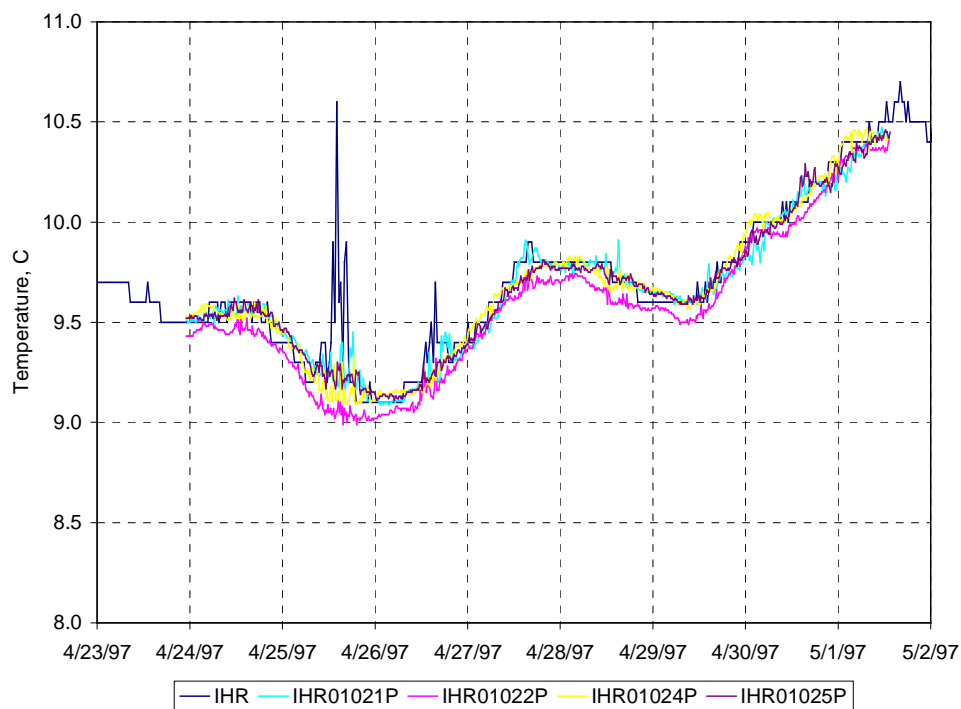
Hourly CHROMS operations data was used to establish the flow at the Ice Harbor dam model boundary. This data provided hourly aggregate spillway flow and power house flow. Hourly spill and powerhouse flows for the Spring 1997 study period are shown in Figure 230. These flows were distributed uniformly across the corresponding part of the model grid.



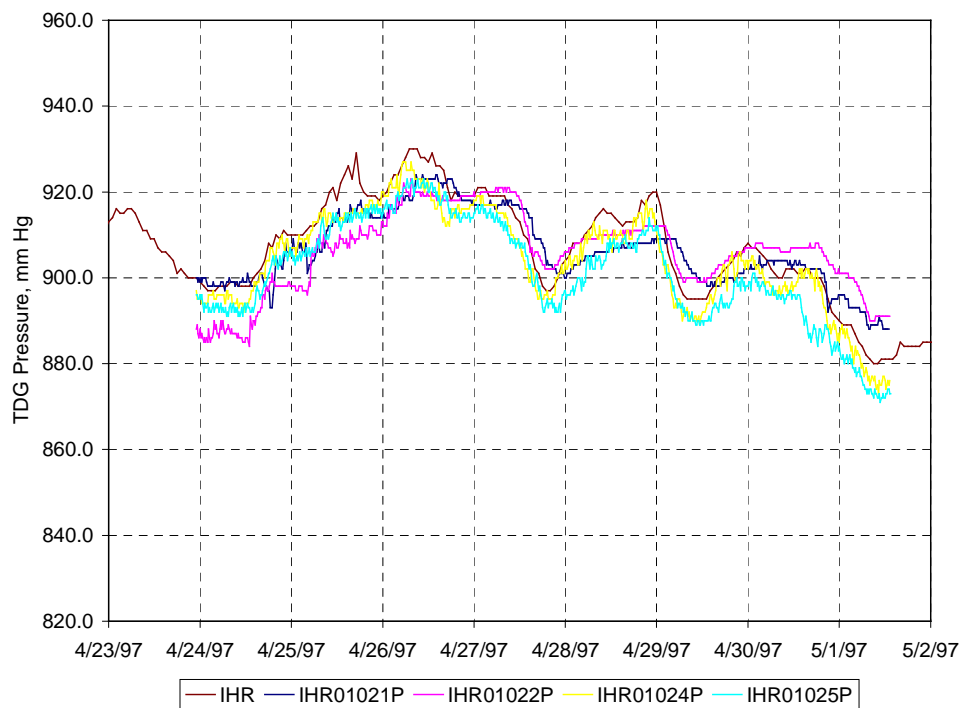
**Figure 230. Ice Harbor Dam operations during the Spring 1997 study.**

#### D.3.2 Water Quality

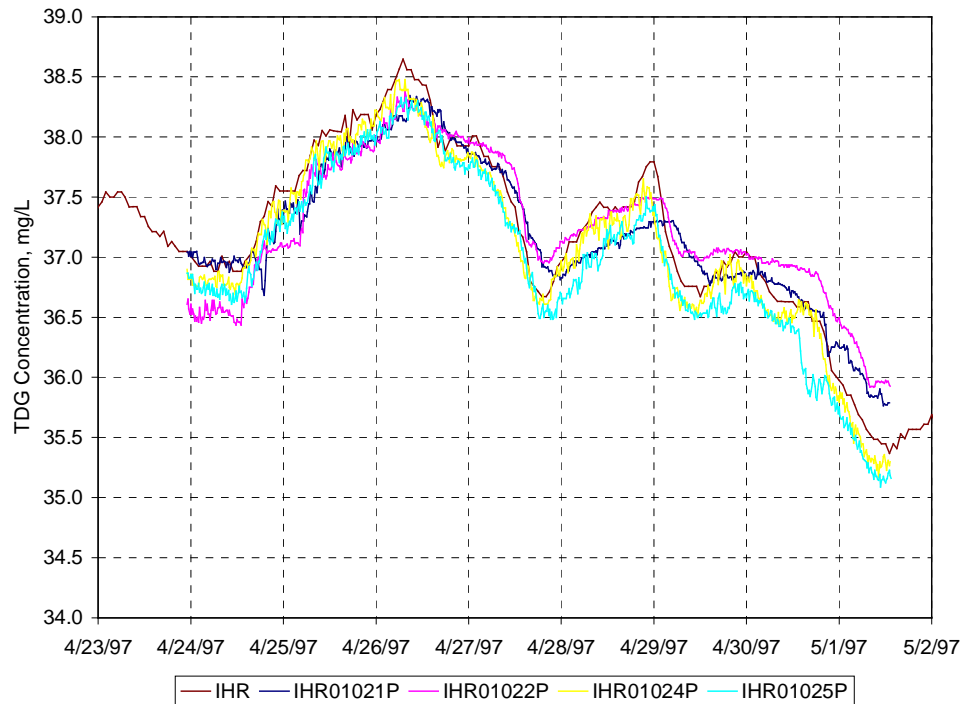
In addition to the fixed monitor located in the Ice Harbor forebay (station name "IHR"), data from four temporary dissolved gas monitors, also in the Ice Harbor forebay, were available for the Spring 1997 study period. Figure 231 and Figure 232 compare recorded temperature and TDG pressure, respectively, from the fixed monitor and the temporary dissolved gas monitors. Figure 233 similarly compares computed concentrations. In general, the fixed monitor and temporary monitors recorded very similar values for temperature and pressure, so the choice of which monitor(s) to use for model boundary conditions was rather arbitrary -- any of the stations could have been used.



**Figure 231. Comparison of temperature recorded by the IHR FMS and temporary water quality monitors in Ice Harbor dam forebay.**

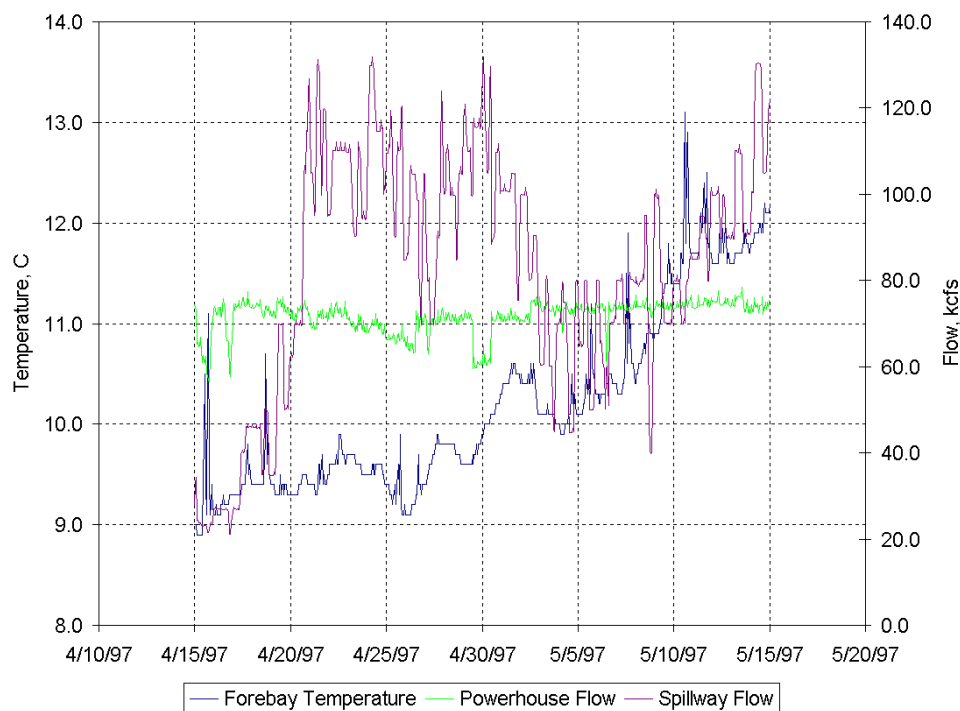


**Figure 232. Comparison of TDG pressures recorded by the IHR FMS and temporary water quality monitors at Ice Harbor dam.**

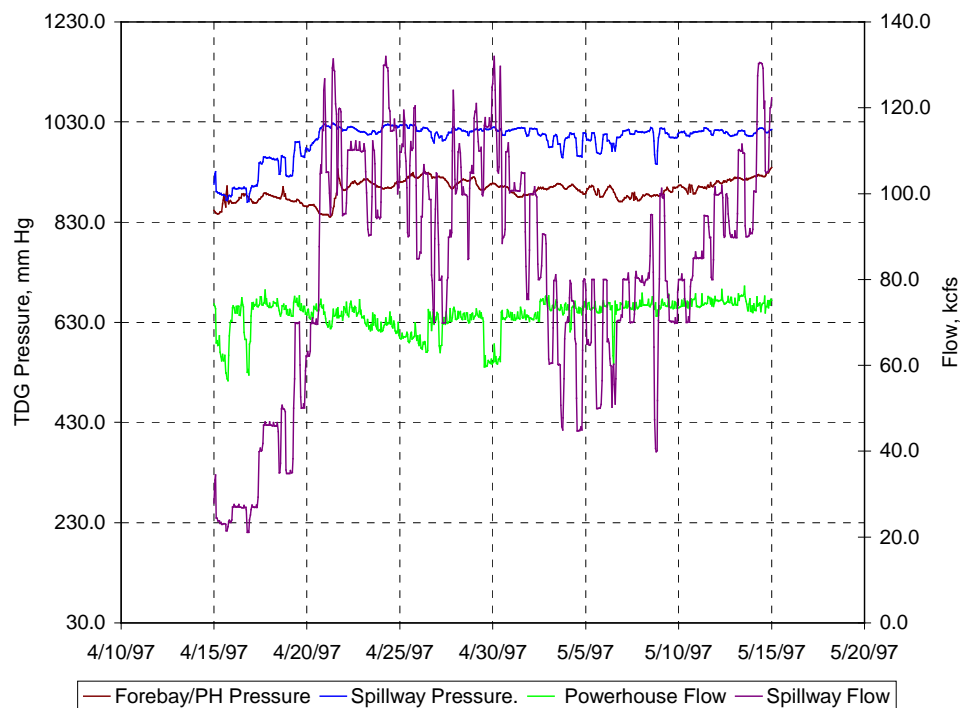


**Figure 233. Comparison of computed TDG concentrations from IHR FMS and temporary water quality monitors at Ice Harbor dam.**

Initially, data from the fixed monitor was used to establish water quality at the Ice Harbor boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 234) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 235) were used to compute TDG concentrations (Figure 236) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 235 and Figure 236, respectively) were estimated using the TDG sourcing function for Ice Harbor dam. The Spring 1997 study took place after the the installation of spill deflectors in 1997. Consequently, the calculated gas concentrations in the spillway using the Ice Harbor sourcing function may not be representative.

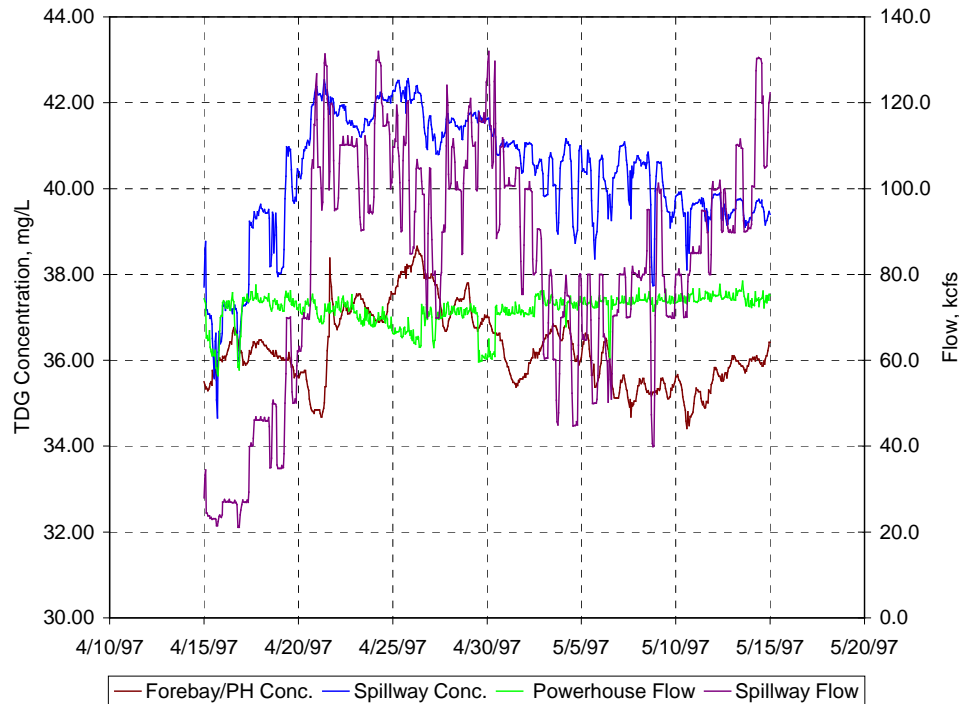


**Figure 234. Water temperature measured by the fixed monitor at Ice Harbor dam during the Spring 1997 study.**



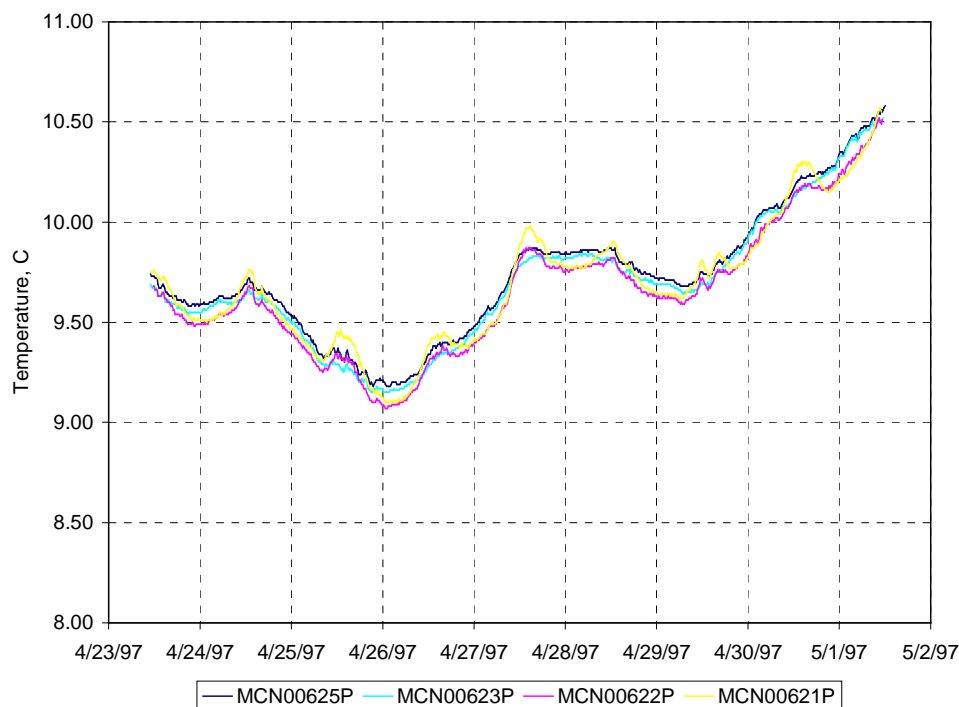
**Figure 235. TDG pressure measured by the fixed monitor at Ice Harbor dam during the Spring 1997 study period.**





**Figure 236. TDG concentration computed from fixed monitor measurements at Ice Harbor during the Spring 1997 study.**

Ice Harbor dam model boundary temperature and dissolved gas concentrations were also established using the temporary pool study monitors. However, since the temporary monitors were located well below Ice Harbor dam, a separate model grid was used. Four temporary monitors were located about three miles below Ice Harbor dam during the Spring 1997 study period. Measured temperatures, measured TDG pressures and computed TDG concentrations from these stations are shown in Figure 237, Figure 238, and Figure 239, respectively. These TDG concentrations were used to establish boundary conditions (at temporary monitor locations) over the appropriate grid cells.



**Figure 237. Water temperature measured by temporary monitors near Ice Harbor dam during the Spring 1997 study.**



**Figure 238. TDG pressure measured by temporary monitors near Ice Harbor dam during the Spring 1997 study period.**

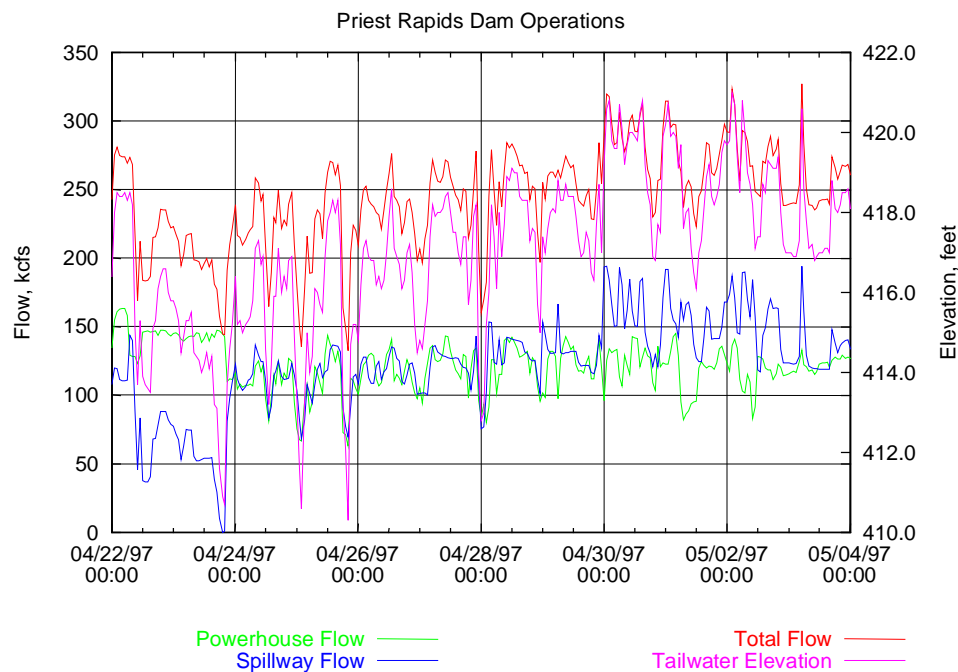


**Figure 239. Computed TDG concentration from temporary monitor measurements near Ice Harbor during the Spring 1997 study.**

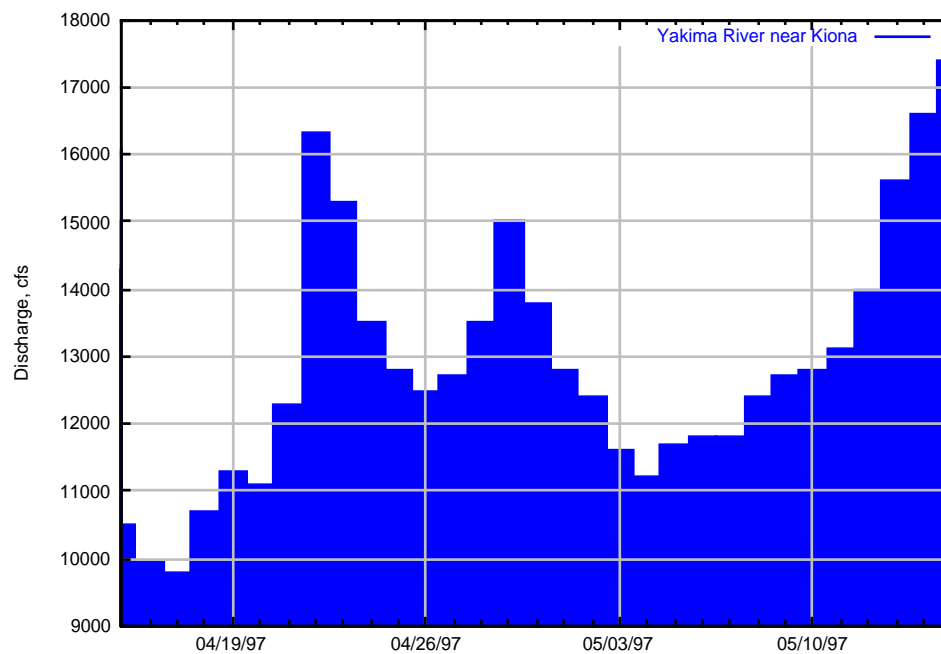
#### ***D.4 Clover Island Boundary***

##### ***D.4.1 Discharge***

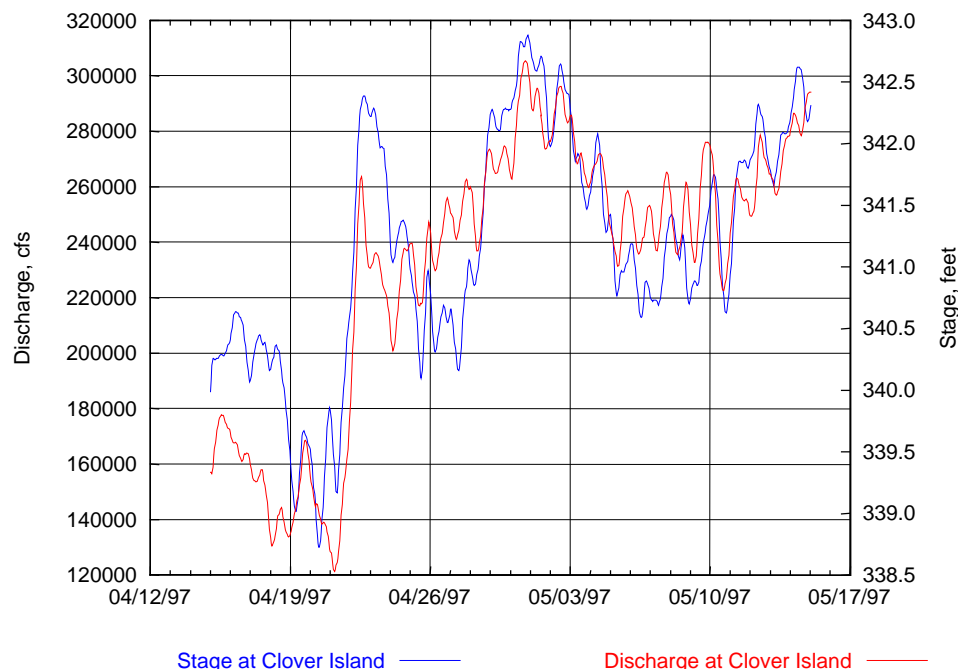
Discharge at Clover Island was estimated using a one-dimensional hydrodynamic model. The model used hourly dam operation data at Priest Rapids dam (Figure 240) and Ice Harbor dam (Figure 230), tributary inflow from the Yakima River (Figure 241), and forebay stages at McNary dam (Figure 246) to predict stage and discharge at Clover Island. Discharge and stage were predicted by the one-dimensional model are shown in Figure 242.



**Figure 240. Priest Rapids dam operations during the Spring 1997 study.**



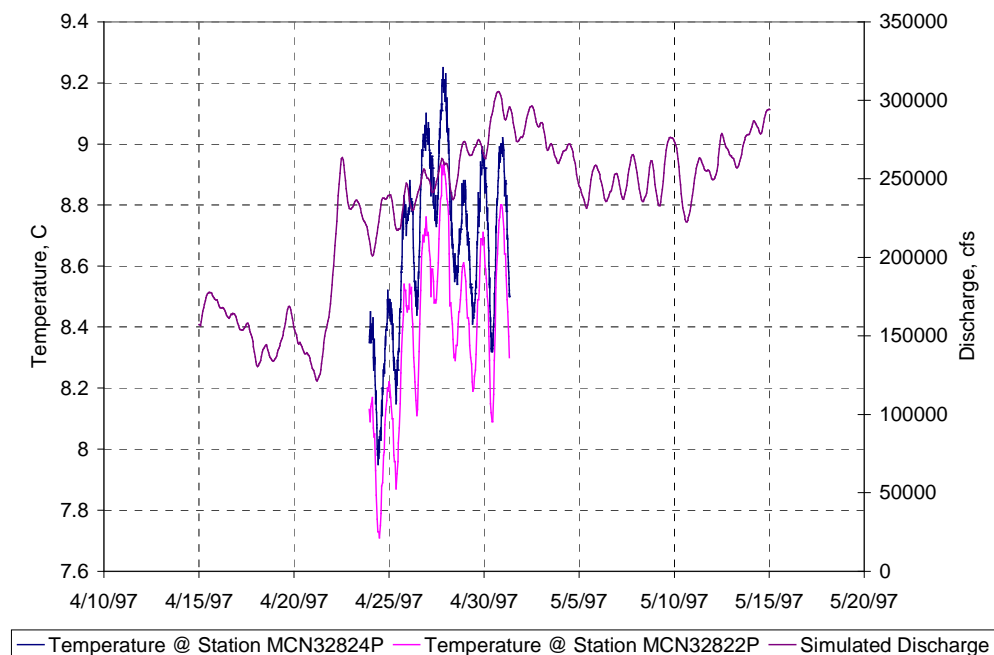
**Figure 241. Yakima River flows during the Spring 1997 study.**



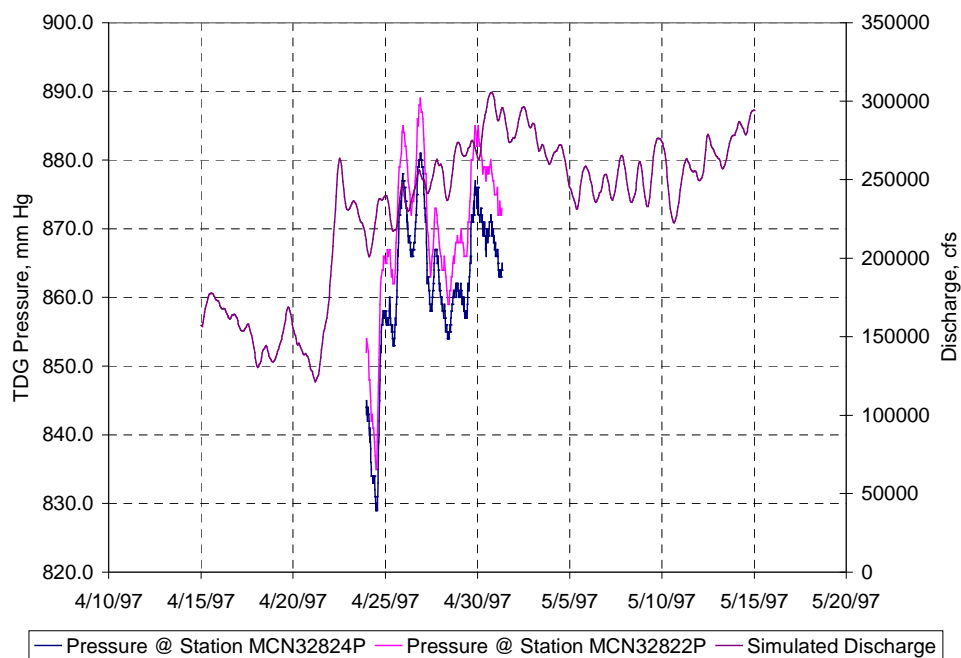
**Figure 242. Predicted discharge at Clover Island during the Spring 1997 study period.**

#### *D.4.2 Water Quality*

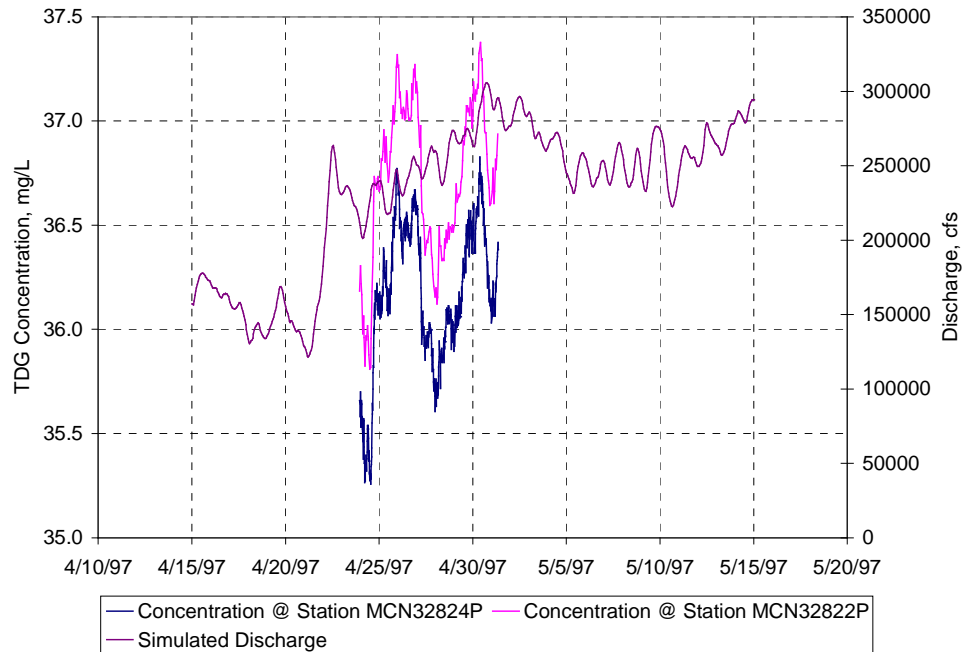
Two temporary water quality monitors were deployed near Clover Island during the Spring 1997 study period: station names "MCN32822P" and "MCN32824P". Temperature (Figure 243) and TDG pressure (Figure 244) measured by the monitor were used for water quality at the Clover Island model boundary. Computed TDG concentrations are shown in Figure 245. Model boundary concentrations were set by applying MCN32824P concentrations to boundary cells 1 through 8 and MCN32822P to cells 9 through 19



**Figure 243. Assumed water temperature for the Clover Island boundary during the Spring 1997 study.**



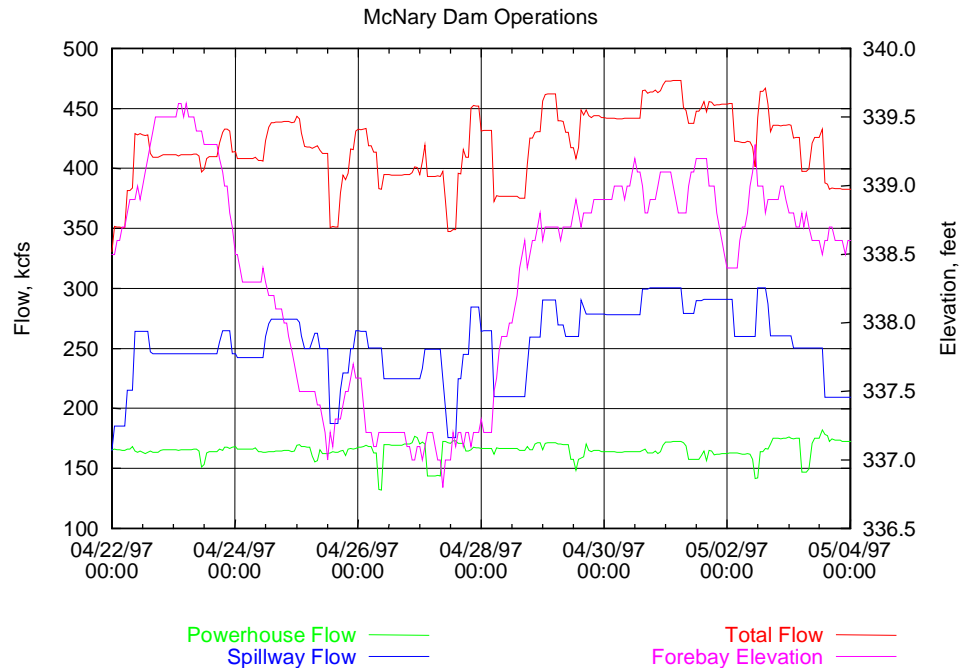
**Figure 244. Assumed TDG pressure for the Clover Island boundary during the Spring 1997 study.**



**Figure 245. Computed TDG concentration for the Clover Island boundary during the Spring 1997 study period.**

#### ***D.5 McNary Dam Boundary Operations***

Forebay stage for McNary dam was obtained from hourly CHROMS operations data and is shown in Figure 246.

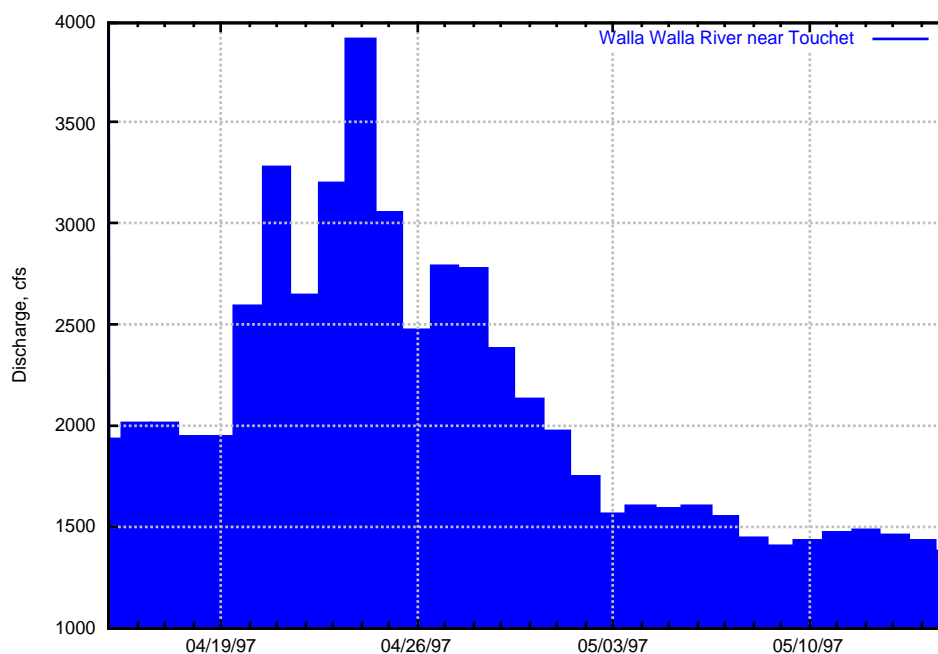


**Figure 246. McNary Dam operations during the Spring 1997 study period.**

#### ***D.6 Walla Walla River Flows***

Flows from the Walla Walla River, shown in Figure 247, during the Spring 1997 study period were relatively low compared to Columbia River flows.

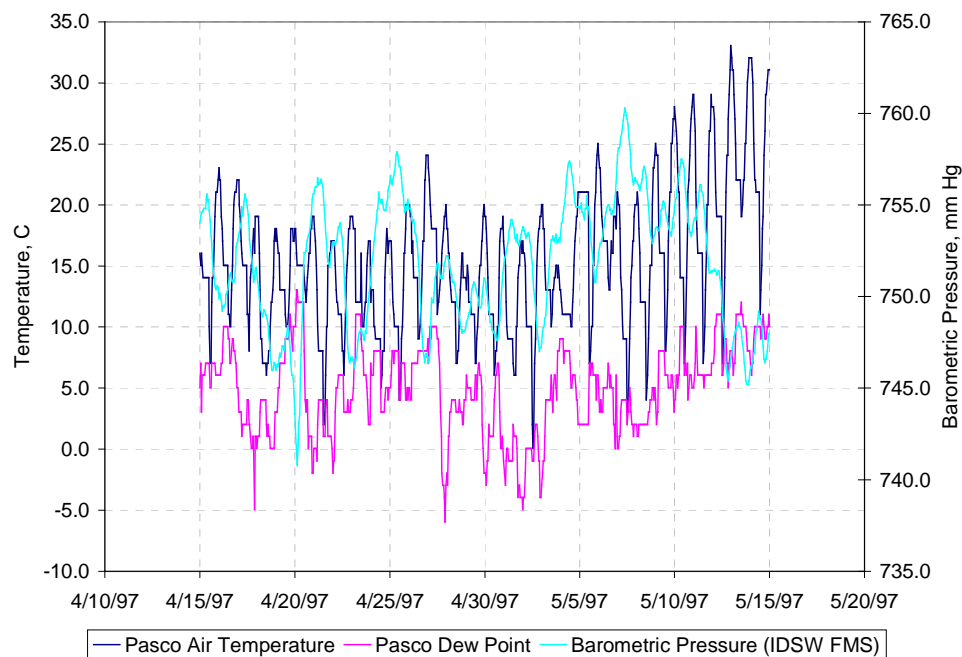




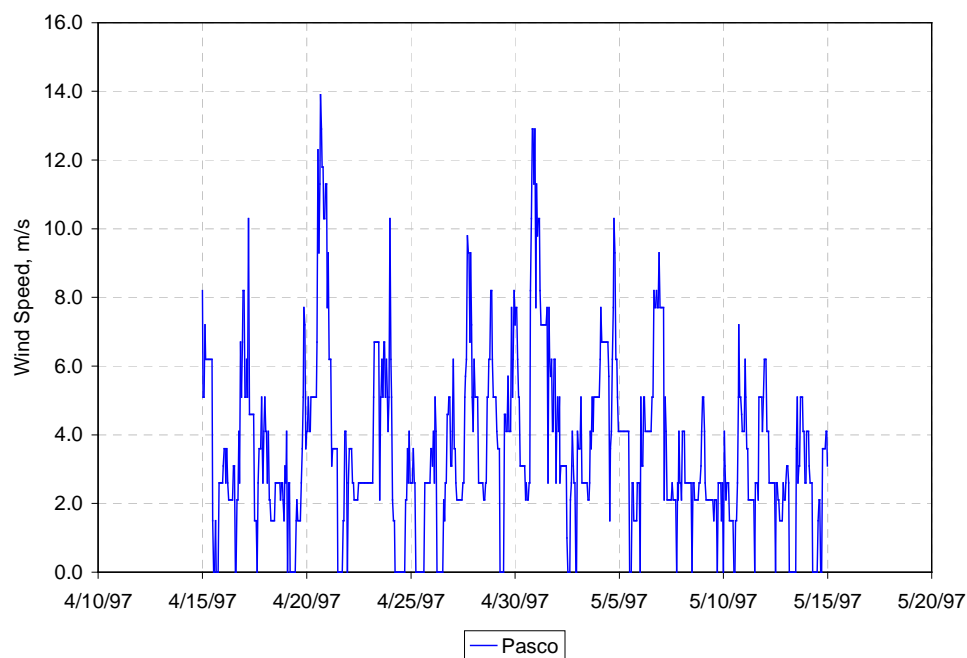
**Figure 247. Walla Walla River flows during the Spring 1997 study period.**

### ***D.7 Weather***

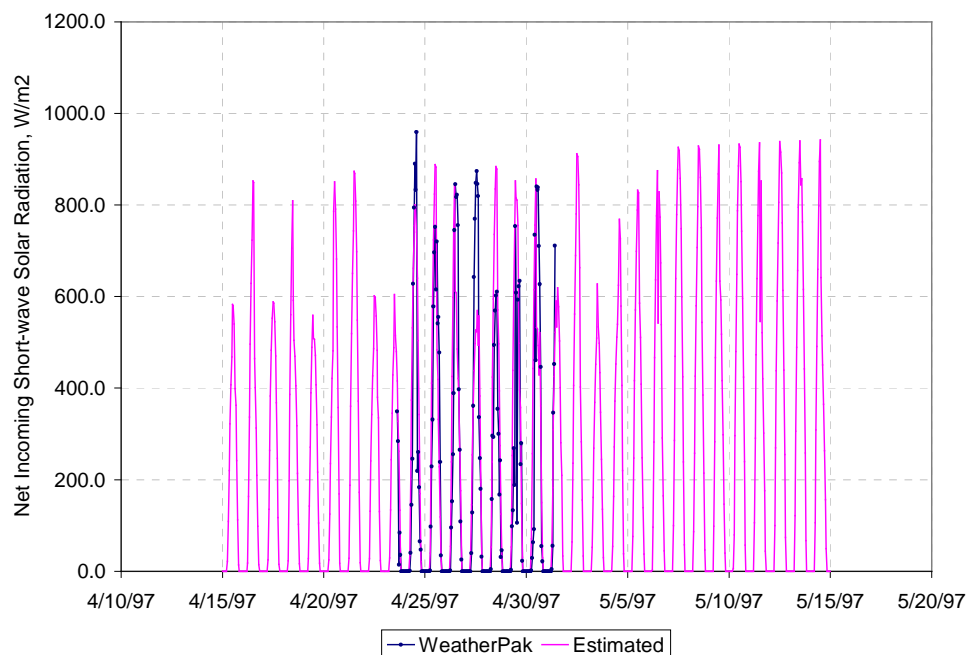
Atmospheric conditions were considered constant over the entire pool. Pasco, Washington, air and dew point temperature (Figure 248) and wind speed (Figure 249) were used from the NWS weather database. Barometric pressure (also shown in Figure 248) measured by the IDSW FMS, downstream of Ice Harbor dam, was considered to apply over the entire modeled area. Short-wave radiation was available from the WeatherPak database for a short time during the Spring 1997 study. That record was extended by estimating total incoming radiation using NWS Pasco dew point and cloud cover data. Cloud cover was assumed to be zero (clear skies) if cloud cover data was missing from the Pasco record. Net incoming solar radiation based both on the estimated total solar radiation is shown in Figure 250.



**Figure 248. Air temperature, dew point, and barometric pressure used during the Spring 1997 study period.**



**Figure 249. Wind speed used during the Spring 1997 study period.**



**Figure 250. Net incoming short-wave solar radiation based estimated total radiation used during the Spring 1997 study period**